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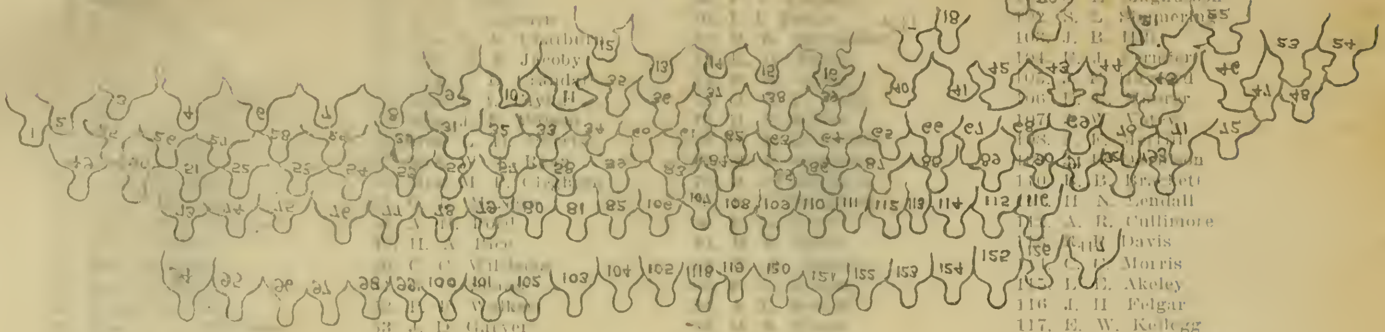

3. W. [illegible]
4. [illegible]

[illegible] Jacoby
[illegible] H. A. [illegible]
[illegible] C. C. Wil[illegible]
[illegible] Walker
53. J. D. Garver
54. S. W. [illegible]
55. R. W. [illegible]
56. B. L. [illegible]
57. W. W. [illegible]
58. B. P. [illegible]
59. C. L. [illegible]
60. [illegible]
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62. [illegible]
63. [illegible]
64. [illegible]

89. J. P. [illegible]
90. P. D. [illegible]
91. H. C. [illegible]
92. C. E. R[illegible]
93. V. L. H[illegible]
94. C. S. N[illegible]
95. J. B. K[illegible]
96. D. S[illegible]

97. G. M. Greene
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99. W. J. Wohlenberg
100. W. J. Risley
101. E. Magnusson
102. S. L. Simmering
103. J. B. Hill
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112. A. R. Cullimore
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1. ———————
2. J. V. Martenis
3. W. T. Ryan
4. Frederic Bass
5. Omitted
6. F. E. Turneaure
7. J. H. Leete
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FOR THE
Promotion of Engineering Education

PROCEEDINGS
OF THE
TWENTY-THIRD ANNUAL MEETING
HELD AT
IOWA STATE COLLEGE, AMES, IOWA
JUNE 22-25, 1915

VOLUME XXIII

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F. L. BISHOP, EDITOR

PITTSBURGH, PA.
OFFICE OF THE SECRETARY
1915

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H. H. Stoek.
J. A. L. Waddell,
A. J. Wood,

Terms of Office Expired in 1915.

F. L Bishop,
G. R. Chatburn,
O. P. Hood,
G. D. Shepardson,
E. P. McKibben.
W. B. Snow,
J. C. Tracy,

---

* Deceased.

DECEASED MEMBERS.

Name.	Year of Election.	Date of Death.	Memoir. Vol. Page.
C. L. Adams	1904	Sept. 16, 1914.	XXII, 414
Philip R. Alger	1909	February 23, 1912.	XX, Part II, 491
William A. Anthony	1907	May 29, 1908.	XVI, 409
George W. Atherton	1904	July 24, 1906.	XIV, 292
Warren Babcock	1908	May, 1913.	XXI, 434
Volney G. Barbour	1894	June 4, 1901.	IX, 340
Charles B. Brush	1893	June 3, 1897.	VII, 181
Storm Bull	1893	November 18, 1907.	XVI, 407
Octave Chanute	1907	November 23, 1910.	XIX, 501
S. B. Charters, Jr.	1911	December 29, 1912.	XX, Part II, 493
S. B. Christy	1893	Nov. 30, 1914.	XXII, 415
Eckley B. Coxe	1894	May 13, 1895.	VII, 182
Chas. S. Denison	1893	July 31, 1913.	XXII, 411
Thomas M. Drown	1895	November 16, 1904.	XII, 244
Chas. B. Dudley	1894	December 21, 1909.	XVIII, 446
Francis R. Fava, Jr.	1894	March 28, 1896.	VII, 183
A. J. Frith	1911	November 10, 1913.	XXI, 435
Estevan A. Fuertes	1894	January 16, 1903.	XI, 372
Henry Fulton	1894	December 6, 1901.	X, 258
John Galbraith	1893	July 22, 1914.	XXII, 410
Thomas Gray	1895	December 19, 1908.	XVII, 238
Wm. F. Gurley	1913	February 17, 1915.	XXII, 417
Herbert G. Greer	1894	March 7, 1900.	VIII, 371
Lyman Hall	1904	August 16, 1905.	XIV, 287
E. L. Hancock	1903	October 1, 1911.	XIX, 505
Albert H. Heller	1903	February 20, 1906.	XIV, 290
H. R. Huelle	1914		
John B. Johnson	1893	June 23, 1902.	X, 259
J. W. Johnson	1907	August 29, 1911.	XIX, 506
Rodney G. Kimball	1894	April 25, 1900.	X, 261
Burton S. Lanphear	1897	October 14, 1904.	XII, 249
Benjamin F. La Rue	1899	December 22, 1903.	XII, 243
N. W. Lord	1907	May 23, 1911.	XIX, 507
C. S. Magowan	1896	November 14, 1907.	XVI, 406
F. O. Marvin	1893	Feb. 11, 1915.	XXII, 416
Charles P. Matthews	1898	November 23, 1907.	XVI, 408
J. D. Newton	1908	August 8, 1912.	XX, Part II, 490

Name.	Year of Election	Date of Death.	Memoir. Vol. Page.
T. M. Phetteplace.....	1903....	September, 7, 1913.	XXI, 436
S. W. Robinson........	1893....	October 31, 1910.	XIX, 510
J. D. Schuyler........	1910....	September 13, 1912.	XX, Part II, 494
Justus M. Silliman...	1894....	April 15, 1896.	VII, 184
T. Guilford Smith.....	1911....	February 20, 1912.	XX, Part II, 492
H. W. Spangler........	1893....	March 17, 1912.	XX, Part II, 488
James H. Stanwood....	1894....	May 24, 1896.	VII, 185
F. H. Stillman........	1911....	February 18, 1912.	XX, Part II, 490
Jos. E. Stubbs.........	1897....	May 27, 1914.	XXII, 412
Fred. W. Taylor	1912....	March 21, 1915.	XXII, 413
Robert H. Thurston...	1893....	October 25, 1903.	XII, 246
Alphonse N. Van Daell.	1897....	March 28, 1899.	VII, 186
J. A. Veazey..........	1911....	August 21, 1911.	XIX, 512
John R. Wagner.......	1894....	January 21, 1899.	VII, 187
Francis A. Walker....	1896....	January 5, 1897.	VII, 188
Howard S. Webb.......	1897....	June 12, 1905.	XIV, 286
Nelson O. Whitney....	1893....	March 17, 1901.	IX, 339
James R. Willett......	1896....	May 9, 1907.	XV, 679
De Volson Wood......	1893....	June 27, 1897.	V, 325
Calvin M. Woodward...	1893....	January 12, 1914.	XXI, 437

GENERAL SUMMARY OF MEMBERSHIP.

July 1, 1915.

Institutions Represented.	
Colleges and Universities Teaching Engineering.	
Domestic	151
Foreign	18
Manual, High, Correspondence and Trade Schools	25
Total Institutions	194
Institutional Members	49
Members	1,403
Total Members	1,452

GROWTH OF MEMBERSHIP.*

Aug. 20, 1894	156	
Sept. 2, 1895	184	
Aug. 20, 1896	200	(about)
Aug. 16, 1897	203	
Aug. 18, 1898	226	
Aug. 17, 1899	238	
July 2, 1900	249	
June 29, 1901	261	
June 27, 1902	253	
July 1, 1903	271	
Sept. 1, 1904	325	
June 28, 1905	379	
July 2, 1906	400	
July 1, 1907	415	
June 27, 1908	675	
June 24, 1909	759	
June, 23, 1910	848	
June 27, 1911	1,071	
June 1912	1,102	
June, 1913	1,158	
March, 1914	1,291	Institutional members.......48
July 1, 1915	1,403	Institutional members.......49

* These figures are taken from the reports of the Secretary, presented at the annual meetings, except the figures for 1914 which were taken from the corresponding year book.

SUMMARY OF MEMBERSHIP BY OCCUPATIONS.

	Teachers	Non-Teachers
Administrative Officers in Industrial, Constructing and Operating Companies	—	84
Architecture	12	7
Deans and Directors only	—	41
Deans and Directors also holding professorships	94	—
Drawing	67	1
Engineering:		
Agricultural	10	2
Ceramic	1	1
Chemical	7	6
Civil	191	60
Electrical	177	61
Experimental	20	—
Gas	14	7
General	18	33
Highway	20	10
Hydraulic	38	—
Industrial and Efficiency	12	12
Irrigation	—	9
Marine	1	—
Mechanical	168	38
Mining	21	1
Municipal, State and Sanitary	19	11
Publicity	—	2
Railway	31	14
Steam	35	10
Structural and Bridge	39	28
Topographic and Geodetic	6	1
English and other Languages	12	—
History and Economics	2	3
Journalists, Librarians and Publishers	—	24
Machine Design	43	6
Manual Training	9	—
Mathematics	111	—
Mechanics and Materials	81	4
Officers of National Societies	—	12
Petrography and Mining Geology	—	1

	Teacher	Non-Teacher
Presidents and other Officers of Educational and Allied Institutions	—	50
Science:		
Chemistry	20	3
Geology	7	4
Metallurgy	10	—
Physics	72	3
Shops and Mechanic Arts	52	—
Trustees of Educational Institutions	—	11
Consulting Engineers	—	42
Various other Occupations	—	33

INSTITUTIONS REPRESENTED IN INDIVIDUAL MEMBERSHIP.

	1913	1914	1915
Acadia University, Wolfville, Nova Scotia	0	0	0
Akron, Municipal University of, Akron, O.	0	2	2
Alabama Polytechnic Institute, Auburn, Ala.	8	8	8
Alabama, University of, University, Ala.	5	5	5
Alberta, University of, Edmonton South, Alta, Canada	1	2	1
Alexander Hamilton Institute, New York, N. Y.	1	1	0
Arizona, University of, Tucson, Ariz.	2	2	3
Arkansas, University of, Fayetteville, Ark.	5	6	5
Armour Institute of Technology, Chicago, Ill.	5	6	6
Berea College, Berea, Ky.	0	0	1
Boston Industrial School for Boys, Boston, Mass.	2	2	2
Bradley Polytechnic Institute, Peoria, Ill.	2	2	2
Brooklyn Manual Training H. S., Brooklyn, N. Y.	1	1	0
Brooklyn Polytechnic Institute, Brooklyn, N. Y.	7	8	9
Brown University, Providence, R. I.	9	9	9
Bucknell University, Lewisburg, Pa.	2	2	2
Buffalo Technical H. S., Buffalo, N. Y.	1	0	0
California, University of, Berkeley, Cal.	7	4	4
Carnegie Institution, Washington, D. C.	1	1	1
Carnegie Institute of Technology, Pittsburgh, Pa.	11	14	14
Case School of Applied Science, Cleveland, O.	17	17	16
Chestnut Hill Academy, Chestnut Hill, Pa.	1	1	1
Chicago, University of, Chicago, Ill.	2	2	2
Christian Brothers College, St. Louis, Mo.	2	2	2
Cincinnati, University of, Cincinnati, O.	8	9	10
Citadel, The, Charleston, S. C.	2	2	2
Clark College, Worcester, Mass.	2	2	2
Clarkson College of Technology, Potsdam, N. Y.	4	4	3
Clemson A. & M. College, Clemson College, S. C.	6	5	5
Cleveland Technical H. S., Cleveland, O.	3	3	3
College of the City of N. Y., New York, N. Y.	1	1	1
Colorado College, Colorado Springs, Colo.	2	2	2
Colorado School of Mines, Golden, Colo.	1	1	1
Colorado State Agri. College, Fort Collins, Colo.	5	6	7
Colorado, University of, Boulder, Colo.	13	19	19
Columbia University, New York, N. Y.	16	15	15
Cooper Union, New York, N. Y.	6	6	6
Cornell College, Mt. Vernon, Ia.	2	1	1

Cornell University, Ithaca, N. Y.	27	25	27
Cumberland University, Lebanon, Tenn	1	1	1
Dartmouth College, Hanover, N. H.	5	6	6
David Rankin, Jr. Sch., St. Louis, Mo.	2	2	2
Delaware College, Newark, Del.	3	4	4
Denver, University of, Denver, Colo.	1	1	1
Dickinson H. S., Jersey City, N. J.	3	3	3
Dorchester H. S., Dorchester Center, Mass.	1	1	1
Drexel Institute, Philadelphia, Pa.	9	11	11
Duval High School, Jacksonville, Fla.	1	1	1
Escola de Engenharia, Porto Alegre, Brazil	1	1	1
Florida, University of, Gainesville, Fla.	5	5	5
Franklin Institute, Philadelphia, Pa.	1	1	1
Franklin Union, Boston, Mass.	5	5	5
George Washington University, Washington, D. C.	2	3	3
Georgia School of Technology, Atlanta, Ga.	1	2	2
Girard College, Philadelphia, Pa.	1	1	1
Government Institute of Technology, Shanghai, China	0	2	3
Harvard University, Cambridge, Mass.	15	14	14
Haverford College, Haverford, Pa.	1	1	1
Hebrew Technical Institute, New York, N. Y.	1	1	1
Highland Park College, Des Moines, Ia.	4	4	4
Idaho, University of, Moscow, Ida.	7	4	4
Illinois, University of, Urbana, Ill.	50	47	48
Indiana University, Bloomington, Ind.	1	1	2
Instituto Technico Professional, Porto Alegre, Brazil	2	2	1
International Correspondence Schools, Scranton, Pa.	5	4	4
Iowa State College, Ames, Ia.	17	21	30
Iowa, State University of, Iowa City, Ia.	7	8	7
James Millikin University, Decatur, Ill.	1	2	1
Johns Hopkins University, Baltimore, Md.	4	5	5
Kansas City M. T. H. S., Kansas City, Mo.	1	1	1
Kansas City N. E. H. S., Kansas City, Mo.	0	1	1
Kansas State Agri. College, Manhattan, Kans.	11	16	30
Kansas, University of, Lawrence, Kans.	7	16	15
Kentucky, State University of, Lexington, Ky.	4	4	4
Lafayette College, Easton, Pa.	4	3	3
Lehigh University, South Bethlehem, Pa.	14	14	14
Leland Stanford Jr. Univ., Stanford Univ., Calif.	3	3	3
Lewis Institute, Chicago, Ill.	3	3	3
Louisiana Industrial Institute, Ruston, La.	2	3	3
Louisiana State University, Baton Rouge, La.	3	3	3
McGill University, Montreal, Canada.	5	5	5
McKinley High School, St. Louis, Mo.	1	1	1

McKinley M. T. S., Washington, D. C.	1	1	1
Maine, University of, Orono, Me.	9	7	8
Manitoba, University of, Winnipeg, Man.	3	3	3
Marquette University, Milwaukee, Wis.	1	1	1
Massachusetts Agri. College, Amherst, Mass.	1	1	1
Massachusetts Inst. of Tech., Boston, Mass.	38	36	38
Mechanics Institute, Rochester, N. Y.	1	1	2
Michigan Agri. College, East Lansing, Mich.	10	11	11
Michigan College of Mines, Houghton, Mich.	8	7	7
Michigan, University of, Ann Arbor, Mich.	20	24	25
Milwaukee Public Schools, Milwaukee, Wis.	1	1	1
Minnesota, University of, Minneapolis, Minn.	31	31	29
Mississippi A. & M. College, Agricultural College, Miss.	8	7	8
Mississippi, University of, University, Miss.	1	1	2
Missouri School of Mines, Rolla, Mo.	2	2	2
Missouri, University of, Columbia, Mo.	14	15	16
Montana Agri. College, Bozeman, Mont.	5	5	5
Montana, University of Missoula, Mont.	1	2	2
Nebraska, University of, Lincoln, Nebr.	13	13	15
Nevada, University of, Reno, Nev.	3	3	3
Newark Manual Training H. S., Newark, N. J.	1	1	1
New Hampshire College of A. & M. Arts, Durham, N. H.	2	1	4
New Mexico Coll. of A. & M. Arts, State College, N. M.	3	3	3
New York Evening High School for Men, New York, N. Y.	1	1	1
New York Military College, Cornwall-on-Hudson, N. Y.	0	0	1
New York University, New York, N. Y.	7	7	7
North Carolina Agri. College, West Raleigh, N. C.	4	4	5
North Carolina, University of, Chapel Hill, N. C.	5	6	6
North Dakota Agri. College, Agricultural College, N. D.	2	2	2
North Dakota State Science School, Wahpeton, N. D.	1	1	1
North Dakota, University of, University, N. D.	5	5	5
Northwestern University, Evanston, Ill.	6	6	6
Norwegian Technical University, Trondhjem, Norway	0	1	1
Norwich University, Northfield, Vt.	1	1	1
Nova Scotia Technical College, Halifax, N. S.	2	2	2
Ohio Northern University, Ada, O.	2	2	2
Ohio State University, Columbus, O.	29	28	29
Oklahoma A. & M. College, Stillwater, Okla.	4	5	4
Oklahoma, University of, Norman, Okla.	4	4	4
Oregon Agri. College, Corvallis, Ore.	5	5	5
Oregon, University of, Eugene, Ore.	3	3	2
Oshkosh Normal School, Oshkosh, Wis.	0	1	2
Pasadena High School, Pasadena, Calif.	1	1	1

Pennsylvania College, Gettysburg, Pa.	1	1	1
Pennsylvania Military College, Chester, Pa.	2	2	2
Pennsylvania State College, State College, Pa.	19	25	24
Pennsylvania, University of, Philadelphia, Pa.	26	30	30
Pittsburgh Central H. S., Pittsburgh, Pa.	1	1	1
Pittsburgh, University of, Pittsburgh, Pa.	10	22	25
Polytechnic School of Engineering, Regents' St., London	1	1	1
Pomona College, Claremont, Calif.	1	1	1
Pratt Institute, Brooklyn, N. Y.	7	7	6
Princeton University, Princeton, N. J.	3	4	5
Purdue University, LaFayette, Ind.	20	19	19
Queen's University, Kingston, Can.	0	2	2
Queensland, University of, Brisbane, Australia	2	2	0
Redlands, University of, Redlands, Calif.	1	0	0
Reed College, Portland, Ore.	1	1	1
Rensselaer Polytechnic Institute, Troy, N. Y.	8	8	8
Rhode Island State College, Kingston, R. I.	2	1	1
Robert College, Constantinople, Turkey	2	3	3
Rose Polytechnic Institute, Terre Haute, Ind.	4	4	4
Rutgers College, New Brunswick, N. J.	6	6	6
Santa Clara, University of, Santa Clara, Calif.	1	1	1
Seattle Engineering School, Seattle, Wash.	0	0	1
Sheffield, University of, Sheffield, England	1	1	1
Southern California, University of, Los Angeles, Calif.	1	1	2
South Dakota State College, Brookings, S. D.	6	5	5
South Dakota, University of, Vermilion, S. D.	1	1	1
St. Johns University, Shanghai, China	1	1	1
Stevens Institute of Technology, Hoboken, N. J.	14	16	16
Swarthmore College, Swarthmore, Pa.	2	2	2
Sydney, University of, Sydney, Australia	1	1	1
Syracuse University, Syracuse, N. Y.	8	7	8
Technical High School, Edmonton, Alberta, Canada	1	1	1
Tennessee, University of, Knoxville, Tenn.	3	3	3
Texas A. & M. College, College Station, Tex.	9	10	10
Texas, University of, Austin, Tex.	4	6	6
Texas State School of Mines and Metallurgy, Fort Bliss, Tex.	0	1	1
Throop College of Technology, Pasadena, Calif.	8	8	8
Tokyo Imperial University, Tokyo, Japan	1	1	1
Toledo University, Toledo, O.	0	1	1
Tome Institute, Port Deposit, Md.	1	0	0
Toronto, University of, Toronto, Canada	10	12	12
Trinity College, Hartford, Conn.	0	1	1

Tufts College, Tufts College, Mass.	12	14	14
Tulane University, New Orleans, La.	3	4	4
Union University, Schenectady, N. Y.	7	7	7
United States Naval Academy, Annapolis, Md.	0	2	2
Universidad de Chile, Santiago, Chile	3	3	3
Utah, University of, Salt Lake City, Utah	6	5	6
Valparaiso University, Valparaiso, Ind.	1	1	1
Vanderbilt University, Nashville, Tenn.	1	1	1
Vermont, University of Burlington, Vt.	8	8	9
Virginia Military Institute, Lexington, Va.	3	3	3
Virginia Polytechnic Institute, Blacksburg, Va.	4	4	4
Virginia, University of, University, Va.	0	6	8
Washington & Lee University, Lexington, Va.	1	2	2
Washington State College, Pullman, Wash.	1	1	1
Washington University, St. Louis, Mo.	6	6	6
Washington, University of, Seattle, Wash.	13	12	12
Wentworth Institute, Boston, Mass.	12	12	12
West Philadelphia H. S. for Boys, Philadelphia, Pa.	1	1	1
West Virginia University, Morgantown, W. Va.	7	7	8
Whitman College, Walla Walla, Wash.	3	3	2
Williamson Free School, Williamson School, Pa.	2	2	2
Wisconsin, University of, Madison, Wis.	26	29	28
Wooster, University of, Wooster, O.	0	1	1
Worcester Polytechnic Institute, Worcester, Mass.	15	16	16
Worcester Trade School, Worcester, Mass.	1	2	2
Wyoming, University of, Laramie, Wyo.	4	3	3
Yale University, New Haven, Conn.	23	23	23

CONSTITUTION

OF THE

Society for the Promotion of Engineering Education

1. NAME—This organization shall be called the SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

2. MEMBERS—Membership in the Society shall be of two general classes, Institutional and Individual.

Institutional members shall be educational institutions giving instruction in engineering and scientific subjects.

Individual membership shall be of two classes, Active and Honorary. It shall comprise those persons who occupy or have occupied responsible positions in the work of engineering instruction, together with engineering practitioners and other persons interested in engineering education.

Honorary Members of the Society shall be such persons as may be recommended by unanimous vote of the Council after a letter ballot. In taking this ballot, the Secretary is directed to close the polls one month after the names of the candidates are sent out. Councilors not heard from will be counted in favor of the candidate. Honorary Members shall not have the right to vote, shall not be eligible to office, and shall not be required to pay any fees or dues.

Any individual member not in arrears for dues may become a Life Member by paying Fifty Dollars into the treasury of the Society at one time.

The name of each candidate for individual membership shall be proposed in writing to the Council by two members by whom he is personally known. In the case of a candidate for Institutional membership the name shall be proposed by any member familiar with the work of the institution on receipt of an application signed by a responsible officer thereof. Such name, if approved by the Council, shall be voted on by the Society at the annual meeting, a vote of three-fourths of those present being required to elect; or, during the period between annual meetings, an affirmative letter ballot of three-fourths of those members of the Council whose vote reaches the Secretary within one month from the time of sending out the name of the candidate shall elect. Such letter ballot elections shall be credited to the previous annual meeting and dues shall date from that time, except that elections to membership occurring after

February 1 shall be credited to the next annual meeting and the dues for the remainder of the year shall be one-half the annual dues.

3. OFFICERS—There shall be a President, two Vice-Presidents, a Secretary and a Treasurer, each to hold office for one year, or until their successors have been elected and have qualified. The Officers shall be elected by ballot of the Society at the annual meeting.

4. COUNCIL—The Council of the Society shall consist of twenty-one elective members, one-third of whom shall retire annually. The Officers and the Past Presidents of the Society shall be members of the Council ex-officio.

Any member of the Society shall be eligible to election to the Council, provided that not more than one elective member shall be from any one college.

Members of the Council shall be elected by ballot by the Society at its annual meeting.

The Council shall constitute a general executive body of the Society, pass on proposals for membership, elect candidates ad interim, attend to all business of the Society, receive and report on propositions for amendments to the constitution, and shall have power to fill temporary vacancies in the offices.

The President of the Society shall be Chairman of the Council, and the Secretary of the Society shall be Secretary of the Council and shall keep the minutes of its meetings and an accurate record of all its actions.

When votes taken by letter ballot of the Council shall be required, all votes which reach the Secretary within one month from the time of sending out the ballots shall be counted, but votes reaching the Secretary later than the time here specified shall not be counted.

5. NOMINATING COMMITTEE—The Nominating Committee shall consist of the Past Presidents and the seven elective members of the Council retiring the following year, provided, however, that if, of this committee, the number in attendance at any meeting be less than five, the President shall make appointments so as to form a committee of five.

6. FEES AND DUES—The admission fee for an individual, active member, which shall also include the first year's dues, shall be Four Dollars ($4.00), and the annual dues, which shall include the subscription price of the BULLETIN, provided for in Art. 8, shall be Four Dollars ($4.00), payable at the time of the annual meeting.

The admission fee for institutional members, which shall also include the first year's dues, shall be Ten Dollars ($10.00), and the annual dues, which shall include the subscription price of three copies of the BULLETIN, and of the PROCEEDINGS, provided for in Art. 8, shall be Ten Dollars ($10.00), payable at the time of the annual meeting.

The fiscal year shall end with the close (or adjournment) of the annual meeting. Those in arrears more than one year shall not be entitled to vote, nor to receive copies of the PROCEEDINGS, and such members shall be notified thereof by the Secretary one month previous to the annual meeting. Any member who has been in arrears more than two years and duly notified by the Secretary, shall be dropped from the roll, until such arrearages are paid.

7. MEETINGS—There shall be an annual meeting at such time and place as the Society at the preceding annual meeting, or the Council may determine.

8. PUBLICATIONS—The publications of the Society shall include an annual volume of PROCEEDINGS, to be published and distributed to the membership as soon as possible after the annual meeting; and a monthly BULLETIN, to be published from September to June, inclusive.

9. AMENDMENTS—This Constitution may be amended by a two-thirds vote of those present at any regular meeting of the Society provided the amendment shall have been approved by the Council by letter ballot by a two-thirds vote of the members voting.

BY-LAWS OF THE SOCIETY AND RULES GOVERNING THE COUNCIL.

First. The Officers of the Society shall constitute a Committee to arrange for the annual meeting and to prepare a program for the same.

Second. The President, the Secretary and the Treasurer shall constitute an Executive Committee which shall have charge of all matters relating to the expenditure of money of the Society, the making of appropriations to Committees and for other purposes, the making of contracts, the approval of bills, and also during the period between the meetings of the Council shall have charge of other business affairs of the Society.

Third. Expenditures of money may be made only in accordance with a definite appropriation or by direct vote of the Executive Committee.

Fourth. Reading of papers shall be limited to fifteen minutes each or to such other time as may be designated by the Program Committee, and abstracts of papers of about three hundred words shall be printed when practicable, and distributed in advance to the members.

Fifth. The time occupied by each person in the discussion of any paper shall not exceed five minutes.

Sixth. The President, the Secretary and the retiring Secretary shall constitute a Publication Committee, of which the Secretary shall be Chairman, to edit and have charge of the publication of the monthly BULLETIN and the PROCEEDINGS of the Society, except the volume of Proceedings of the last convention, which shall be edited by the retiring

Secretary. If at any time there be no retiring Secretary the retiring President shall be a member of this Committee.

Seventh. The Officers, members of the Council and members of the local Convention Committee shall constitute a Committee on Sociability to introduce members and guests to each other at the annual meetings and in general to promote a spirit of good fellowship.

Eighth. The subscription price of the BULLETIN shall be One Dollar per year, payable in advance.

Ninth. Additions or amendments may be made to these By-Laws at any regular meeting of the Society, on the recommendation of the Council by a two-thirds affirmative vote of the Council and of the Society.

PUBLICATIONS.

The publications of the Society can be obtained from the Secretary. The current issues are distributed gratuitously to members in good standing, one copy of each to each individual member and three to each institutional member. The price of the bound volumes of the PROCEEDINGS of former years is $2.50 to non-members, $2.00 to public libraries, and $1.50 to members for their own libraries.

The BULLETIN is issued monthly from September to June. The price to non-members is $2.00 per year. Libraries may order the BULLETIN and the PROCEEDINGS at $4.00 per year.

Reprints of papers may be ordered when the papers are in type form, and either with or without covers, at a price depending upon the number of pages and copies desired.

Society for the Promotion
of
Engineering Education
Ames Meeting
June 22-25

* * *

Program
of the
Twenty-third Annual Meeting
Iowa State College
Ames, Iowa
1915

General Information

REGISTRATION AND INFORMATION.

Registration, information, executive and business headquarters will be in ROOM 212, ENGINEERING HALL, just across the corridor from the assembly room.

MEETING PLACE.

All meetings of the Society will be held in Engineering Assembly, 207 ENGINEERING HALL. Meetings of the Council will be held in an adjoining room.

MEALS.

Meals will be served at the College Inn on the campus, which is only a minute's walk from Engineering Hall. Meals will be 50c.

RECREATIONS.

The tennis courts, gymnasium, swimming pool, shower baths and golf links will be open to visitors. The Ames Golf and Country Club will be open during the session with full privileges for the visiting members.

EXCURSIONS.

Automobile trips have been planned over the Lincoln Highway to view the Iowa road work, to see something of Iowa farm scenery, the construction of culverts and bridges, and probably an opportunity for inspection of the double-track viaduct over the Des Moines River on the Chicago and Northwestern Railroad. Another feature proposed is a trolley trip to the gypsum mines at Fort Dodge. For detailed information consult information bureau.

Program

Tuesday, June 22

11:30 A. M. Meeting of Council.

2:00 P. M. Opening session, President Marston presiding.

Address of Welcome,
Raymond Allen Pearson, President Iowa State College.

Response,
Past-President Gardner C. Anthony.

3:00 P. M. Business Session:

Report of Treasurer.

Appointment of Auditing Committee.

Report of Secretary.

Election of members.

Appointment of committees on resolutions and nominations.

Announcements by local committee.

3:30 P. M. Report of Committee on Classification of Colleges,
President C. S. Howe.

Report of the Joint Committee on Engineering Education,
Dean G. C. Anthony.

Address,
Dr. C. R. Mann, Carnegie Foundation for the Advancement of Teaching.

Paper, The Education of the Future Engineer,
Dean C. L. Cory.

Report of the Committee on Entrance Requirements,
Professor J. J. Flather.

Report of the Committee on Teaching Mathematics to Students of Engineering,
Professor E. V. Huntington.

4:45 P. M. Organization meeting of the institutional delegates,
Vice-President C. Russ Richards presiding.

5:00–6:30 P. M. Reception for visiting members and ladies, by President Pearson and Dean Marston, at the home of President Pearson.

8:00 P. M. Annual Society Smoker.

Wednesday, June 23

9:00 A. M. Meeting of Council.

9:30 A. M. Business Session, President Marston presiding.

9:45 A. M. Report of Committee on Teaching Mechanics to Students of Engineering,
Professor E. R. Maurer, presiding.

Report of Committee on Teaching Physics to Students of Engineering,
Professor D. C. Miller presiding.

Report of Committee on Coöperation with Secondary Schools.
Professor H. E. Webb.

Report of Committee on Statistics,
Professor A. J. Wood.

Paper, Instruction in Illuminating Engineering.
Professor L. B. Spinney.

11:45 A. M. Meeting of institutional delegates,
Vice-President C. Russ Richards presiding.

Wednesday afternoon and evening have been set aside for two distinct trips for visiting members and ladies. These are arranged as alternates, the one preferred to be chosen:

(a) Automobile trip over Lincoln Highway, Ames to Jefferson and return. Side inspection trips will be made to some of the leading drainage projects of the State and to the famous C. & N. W. Ry. double-track viaduct across the Des Moines River. Supper at Boone.

(b) Des Moines River-Fort Dodge trolley trip, including inspection of power plants, clay and gypsum manufacturing plants. Supper at Fort Dodge.

Thursday, June 24

9:00 A. M. Meeting of Council.

9:30 A. M. Business Session, President Marston presiding.
Report of Auditing Committee.
Report of Committee on Nominations.
Election of Officers.
Report of Committee on Standardization of Technical Nomenclature,
Professor J. T. Faig.
Report of Committee on Improvements in Laboratory Instruction,
Professor C. F. Scott, (Electrical).
Professor A. M. Greene, Jr., (Mechanical).
Professor F. W. Sperr, (Mining).
Professor F. P. McKibben, (Civil).
Paper, Class and Laboratory Work in Engineering,
Professor W. C. Bauer.
Paper, Laboratory Efficiency Tests for Students in Chemical Engineering,
Professor D. F. McFarland.
Paper, Engineering Thermodynamics at American Colleges,
Dean A. A. Potter.

12:00 M. The Faculty ladies will give a luncheon to the visiting ladies.

1:30 P. M. Paper, Methods of Teaching Industrial Management at the University of Kansas,
Dean P. F. Walker.
Paper, Shop Instruction at the University of Illinois, (Illustrated), Director B. W. Benedict.
Paper, Woodworking for Mechanical Engineering Students,
Mr. A. S. Kinsey.
Paper, Coordinating Draughting and Shop Work.
Professor F. G. Higbee.
Paper, The Architectural Course at Wentworth Institute,
Principal A. L. Williston.

4:00 to 6:00 P. M. Reception for visiting members and ladies at the home of Dean Curtiss.

6:30 P. M. Annual Dinner.
Address, Senator A. B. Cummins.
Presidential address, Dean Anson Marston.
The Relation of the Engineering Schools to the Profession, the State, and the Public.

Friday, June 25

9:00 A. M. Meeting of Council.

9:30 A. M. Business Session, President Marston presiding.

Report of Committee on Resolutions.

9:45 A. M. General Session: Administration.
President Marston presiding.

Paper, The Annual Competition Conducted by the Engineers' Society of Western Pennsylvania,
Dean John H. Leete.

Paper, Efficiency in College Administration,
Chancellor S. B. McCormick.

Paper, Reflections of a Director,
Director J. F. Hayford.

Paper, Some Important Questions in Engineering Education,
Dr. J. A. L. Waddell.

Paper, The Value of Final Examinations,
Dean E. D. Walker,

12:00 M. Meeting of Institutional Delegates, Vice-President C. Russ Richards presiding.

12:30 P. M. Adjournment.

LOCAL COMMITTEES FOR THE S. P. E. E. CONVENTION.

June 22-25, 1915.

GENERAL COMMITTEE.

Dean R. E. Buchanan, *Chairman.*

Dean C. H. Stange,
Dean C. J. MacKay,
Professor S. A. Beach,
Professor S. W. Beyer.
Professor M. M. Roberts,
Professor W. H. Meeker,
Honorable Parley Sheldon,
Mr. Carl L. Little,
Mr. E. W. Valentine,
Mr. Thomas R. MacDonald,
Mrs. A. Marston,
Mr. C. S. Nichols.

HOUSING COMMITTEE.

Professor W. H. Meeker, *Chairman.*

Professor J. B. Davidson,
Professor T. R. Agg,
Professor A. H. Kimball,
Professor J. E. Kirkham,
Professor F. A. Fish,
Professor L. B. Spinney,
Professor J. T. Bates,
Director K. G. Smith,
Mr. John H. Ames,
Mr. H. W. Wagner.

ENTERTAINMENT COMMITTEE.

Vice-Dean S. W. Beyer, *Chairman.*

Professor T. R. Agg,
Professor E. E. King,
Professor F. D. Paine,
Professor J. B. Davidson,
Professor R. H. Porter,
Professor Harold Stiles,
Mr. D. C. Faber,
Mr. John S. Dodds.

LADIES ENTERTAINMENT COMMITTEE.

Mrs. A. Marston, *Chairman.*

Mrs. S. W. Beyer,
Mrs. J. B. Davidson,
Mrs. F. A. Fish,
Mrs. T. H. MacDonald,
Mrs. J. E. Kirkham,
Mrs. E. E. King,
Mrs. M. P. Cleghorn,
Miss Maria M. Roberts,
Mrs. Emily Cunningham,
Mrs. Herman Knapp,
Mrs. L. H. Pammel,
Mrs. W. F. Coover,
Mrs. E. C. Potter,
Mrs. H. J. Plagge,
Mrs. L. Pearson,
Mrs. E. W. Stanton,
Mrs. C. F. Curtiss,
Mrs. R. E. Buchanan,
Mrs. C. H. Stange,
Dean Catharine J. MacKay,
Mrs. S. A. Beach,
Mrs. A. B. Noble,
Mrs. W. H. Stevenson,
Mrs. O. H. Cessna,
Miss Elizabeth MacLean.

INFORMATION BUREAU.

Room 212 Engineering Hall.

Mr. C. S. Nichols,
Mr. Carl H. Schemann.

MINUTES OF THE TWENTY-THIRD ANNUAL MEETING.

AMES, IOWA.

JUNE 22 TO JUNE 25, 1915.

The twenty-third annual meeting of the Society for the Promotion of Engineering Education was held at The Iowa State College, Ames, Ia., June 22 to 25, 1915. The sessions were held in the Engineering Assembly, 207, Engineering Hall. Registration headquarters were in Room 212, Engineering Hall.

TUESDAY, JUNE 22.

Afternoon Session.

The meeting was called to order at 2:00 P. M. by President Anson Marston, dean of the division of engineering of The Iowa State College, who introduced President Raymond Allen Pearson of The Iowa State College. President Pearson delivered the address of welcome. Dean Gardner C. Anthony of Tufts College, Past-President, responded for the Society.

The Treasurer, Mr. W. O. Wiley, presented his annual report, which on a motion was received and referred to the Auditing Committee. President Marston then appointed Professors W. S. Rodman, W. B. Russell and J. F. Wilson as the Auditing Committee. A list of twenty-three applicants, which had been approved at a Council meeting held at noon, was favorably acted upon by the Society. One application for institutional membership was also approved.

Library
N. C. State College

The Secretary read by title a list of resignations which were ordered accepted when the constitutional requirements had been complied with.

The President announced the following names of the members of the Committee on Resolutions: Professors F. C. Caldwell, C. H. Crouch and C. E. Magnusson.

President Marston then called for the presentation of the report of the Committee on the Classification of Colleges by Professor C. S. Howe. On motion the report was accepted and the committee continued. In the absence of Mr. FitzGerald, Chairman of the Joint Committee on Engineering Education, Dean G. C. Anthony read a report of progress. Dr. C. R. Mann then made a special report on this same subject. A discussion of these reports followed.

Dean C. L. Cory then presented his paper, "The Education of the Future Engineer." A motion was made, seconded and carried that a committee be appointed to investigate conditions relative to the summer employment of engineering instructors.

WEDNESDAY, JUNE 23.

Morning Session.

The meeting was called to order at 9:45 with President Marston in the chair. The Secretary, Dean F. L. Bishop, having a slight attack of tonsillitis, the Assistant Secretary, Professor L. H. Harris, presented the report of the meeting of Council. This report recommended that the Committee on Committees be a standing committee, and that it have general authority over the work of the other committees of the Society. Upon a motion being made and seconded this report was adopted as read. The council also recommended that the report of the Nominating Committee be read at this meeting. The Nominating Committee reported as follows:

For officers to serve for one year:

For President: Henry S. Jacoby, Cornell University.

For First Vice-President: G. R. Chatburn, University of Nebraska.

For Second Vice-President: F. H. Constant, Princeton University.

For Secretary: F. L. Bishop, University of Pittsburgh.

For Treasurer: W. O. Wiley, New York.

For members of the Council to serve for three years: L. P. Breckenridge, Yale University; C. L. Cory, University of California; C. H. Crouch, University of North Dakota; O. P. Hood, Pittsburgh, Pa.; F. P. McKibben, Lehigh University; G. D. Shepardson, University of Minnesota, and J. B. Whitehead, Johns Hopkins University.

On motion the Secretary was instructed to cast a unanimous ballot in favor of all the above candidates.

President Anson Marston: I take great pleasure in introducing the President for the next year, Professor H. S. Jacoby.

Professor H. S. Jacoby: I am very grateful indeed for the honor conferred upon me by granting me the opportunity to serve the Society for the coming year. I realize fully the obligations, and the responsibility thus placed on my shoulders; but it is because I feel that you are willing to stand with sympathetic spirit to co-operate heartily and that the other officers are likewise glad to help in this work, that I expect to go forward with good cheer. I will try to do my best. and shall always be glad to receive suggestions and advice which you think will do the President good in order to carry on the work properly.

An invitation from Dean Adolph Shane to visit Highland Park College any time during the week, was then read. Professor E. R. Maurer read the report of the Committee on Teaching Mechanics to Engineering Students. Professor Maurer presided at the meeting during the discussion which followed. Professor D. C. Miller read the report of the Committee on Teaching Physics to Students of Engineering. He also presided at the meeting during the discussion of this report. Professor C. M. Wirick presented an abstract of the report of the Committee on Coöperation with Secondary Schools.

Thursday, June 24.

Morning Session.

The meeting was called to order at 9:30 with President Marston in the chair. Professor Wilson reported for the Auditing Committee that the books of the Treasurer were found in good condition, the cash balance tallying with the report made by that officer. On motion it was voted to receive the report and discharge the Committee. In the absence of the Chairman, Professor A. J. Wood, Professor F. A. Fish read the report of the Committee on Statistics. Professor L. B. Spinney then read his paper on "Instruction in Illuminating Engineering." Dean G. C. Anthony presented the report of the Committee on the Standardization of Technical Nomenclature. The Secretary reported for the Committee on Improvements in Laboratory Instruction. Professor W. S. Bauer read his paper on "Class and Laboratory Work in Engineering." The meeting was then thrown open for the discussion on laboratory instruction. Two other papers were read before the meeting adjourned. These papers were "The Annual Competition Conducted by the Engineers' Society of Western Pennsylvania," by Dean John H. Leete and "Engineering Thermodynamics at American Colleges" by Dean A. A. Potter. Discussion on these papers was deferred until afternoon.

Afternoon Session.

The afternoon session was called to order at 1:30 with President Marston in the chair. Dean P. F. Walker read his paper on "Methods of Teaching Industrial Management at the University of Kansas." Director B. W. Benedict then presented an illustrated paper on "Shop Instruction at the University of Illinois." Mr. A. S. Kinsey not being present, his paper on "Woodworking for Mechanical Engineering Students" was read by title. After Professor F. G. Higbee read his paper "Coördinating Draughting and Shop Work" and Principal A. S. Williston his paper on "The Architectural Course at Wentworth Institute" the meeting was thrown open for the discussion of these papers.

Annual Dinner—Thursday Evening.

The annual dinner was held in Margaret Hall Gymnasium. Senator A. B. Cummins spoke on behalf of the State of Iowa, and President Marston delivered his presidential address on the subject "The Relation of the Engineering Schools to the Profession, the State, and the Public."

FRIDAY, JUNE 25.

Morning Session.

The Society convened at 9:30 with President Marston in the chair. Professor F. C. Caldwell, chairman of the Committee on Resolutions, presented the following resolutions which were duly passed:

The Society desires to express its appreciation of the courtesies and favors extended to its members and visiting ladies by the administration and members of the faculty of the Iowa State College and to all others who have contributed to the success of the convention of 1915. Therefore, be it

Resolved: That the thanks of the Society be hereby tendered to President Pearson, Dean Marston, Dean Curtis and the ladies of the faculty for their cordial hospitality; to the local members of the Society for their untiring efforts for the success of the meeting; to the Ames Golf and Country Club, the City Commercial Club, the Holst Hotel management and the Fort Dodge Commercial Club for the very enjoyable entertainment provided; to the Fort Dodge, Des Moines and Southern Railway and the Plymouth Clay Products Company of Fort Dodge for permitting the members of the Society to visit their works; to the State Highway Commission for its thoughtful efforts in our behalf; and to the many who sacrificed their personal comforts in order to provide the members with convenient quarters during their stay.

Professor H. S. Jacoby then presented the report of the Committee on Committees which had been adopted by the Council. It was moved, seconded and carried that the recommendations as presented by the Council be approved. Professor Jacoby also presented to the Society, for its approval, the report of the Institutional Delegates. Report adopted. After the adoption of this report it was moved that no papers received after May first be considered at the annual meetings of the Society, except by unanimous consent of the Program Committee. After a discussion this motion was amended to read "May fifteenth" instead of "May first" and the motion, as amended, was put to a vote and carried.

Dr. J. A. L. Waddell then read a paper entitled "Some Important Questions in Engineering Education." The discussion of this paper was postponed until after the reading by Director J. F. Hayford of his paper on "Reflections of a Director." A discussion of the two papers then followed. The convention then adjourned *sine die*.

SOCIAL FEATURES OF THE AMES MEETING.

Owing to the widely prevalent belief in the value of the social side of the meetings, an effort was made to emphasize this phase of the program as much as possible consistent with the necessary business. A good start was made when a special car from Chicago to Ames was arranged for. The car was completely filled by members and the occasion added much to the enjoyment of the trip. Automobiles met the train at Ames and conveyed the party to the campus.

Tuesday afternoon a reception was held at the home of President Pearson with President Pearson and Dean Marston as joint hosts. This was the first of the social meetings and preceded by only a few hours the annual smoker at the Ames Golf and Country Club. Special cars carried the party to the club house, which is located about two miles from the campus. Smokes, refreshments, and entertainment made the evening seem short indeed.

Wednesday morning the visiting ladies were taken for an auto ride over the campus and through the city. The men's turn came in the afternoon, which had been set aside for recreation. Two trips had been planned by the local committee, between which it was necessary, though difficult, to choose. One was an auto ride over the Lincoln Highway west with supper at Boone. This provided opportunity to see something of Iowa farm country and also something of the work of the State Highway Commission, of which Dean Marston is chairman. The other trip was made by trolley to Ft. Dodge to inspect industrial and mining operations there, with supper at Ft. Dodge.

Thursday noon the visiting ladies were entertained at a luncheon given by the ladies of the faculty. A feature of this luncheon was the opportunity given to inspect the Home Economics Building. The luncheon was served in this building and the food prepared by the students specializing in that work.

In the afternoon visiting members and ladies were received at the home of Dean Curtis.

On Thursday evening was held the annual Society dinner—the big event of the meetings. It is an established custom to hold this on the third evening in order that all late comers may have an opportunity to attend. We were especially fortunate in having as the guest of honor, the Hon. A. B. Cummins, United States Senator from Iowa, who spoke on what Dean Marston claimed to be his favorite theme, "Iowa."

Not the least enjoyable of all the social arrangements was the result of the work of the housing committee. All of the visiting members were grouped, in so far as was practicable, in the new dormitory and in Alumni Hall. A good word must also be said for the quality of the food, which was uniformly excellent.

The committee did not say who had the weather in charge, but it was evidently some one in high authority or of great influence, for an unusual stretch of fine weather prevailed.

The trip down from Chicago proved so enjoyable that a special car was arranged for to leave Friday noon for Chicago, postponing until the last the final disbanding of the members.

ATTENDANCE AT THE CONVENTION.

One hundred and seventy-seven members and guests registered at the convention. The names follow, those of institutional delegates and members representing institutions being indicated by asterisks: T. R. Agg, Mrs. T. R. Agg, L. E. Akeley, G. C. Anthony, F. E. Ayer*, I. O. Baker, H. C. Bartholomew, Mrs. H. C. Bartholomew, F. Bass, J. T. Bates, W. C. Bauer, B. W. Benedict, W. A. Bevan, S. W. Beyer*, Mrs. S. W. Beyer, F. L. Bishop*, G. W. Bissell, D. W. Blakeslee, F. C. Bolton, B. B. Brackett, G. M. Braune, F. C. Caldwell, W. W. Carlson, E. F. Chandler, G. A. Chaney, Mrs. G. A. Chaney, G. R. Chatburn, Mrs. G. R. Chatburn, M. P. Cleghorn, Mrs. M. P. Cleghorn, E. F. Coddington, C. I. Corp, Mrs. C. I. Corp, C. L. Cory*, M. F. P. Costelloe, Mrs. M. F. P. Costelloe, C. L. Crandall*, Mrs. C. L. Crandall, C. H. Crouch*, R. W. Crum, Mrs. R. W. Crum, J. B. Davidson, Mrs. J. B. Davidson, H. K. Davis, R. P. Davis, J. F. H. Douglas, Mrs. J. F. H. Douglas, F. A. Dragoun, Mrs. F. A. Dragoun, H. T. Eddy, H. S. Evans, M. I. Evinger, D. C. Faber, Mrs. D. C. Faber, J. H. Felgar, O. J. Ferguson, R. H. Fernald, Mrs. R. H. Fernald, E. J. Fermier, F. A. Fish, Mrs. F. A. Fish, B. P. Fleming, Mrs. B. P. Fleming, A. H. Ford, H. C. Ford, Mrs. H. C. Ford, W. S. Franklin, S. L. Galpin, Mrs. S. L. Galpin, J. D. Garver, R. W. Gay, L. H. Harris, Mrs. L. H. Harris, J. F. Hayford*, G. E. Hesse, F. G. Higbee, W. A. Hildreth, A. H. Hoffman, J. D. Hoffman, V. L. Hollister, C. S. Howe*, H. S. Hower, H. S. Jacoby, Mrs. H. S. Jacoby, J. B. Kelley, Mrs. J. B. Kelley, M. A. R. Kelley, E. W. Kellogg, M. S. Ketchum*, A. W. Keuffel, E. E. King, Mrs. E. E. King, J. E. Kirkham, Mrs. J. E. Kirkham, L. C. Kyle, John Leete*, H. N. Lendall*, O. A. Leutwiler, J. J. Long, E. J. McCaustland, G. B. McNair, C. E. Magnusson*, C. R. Mann, A. Marston, Mrs. A. Marston, J. V. Martenus, Mrs. J. V. Martenus, E. R. Maurer, W. H. Meeker, J. F. Merrill*, D. C. Miller, C. C. Morris, B. L. Newkirk, F. D. Newton, C. S. Nichols, Mrs. C. S. Nichols, O. A. Olson, Mrs. O. A. Olson, F. D. Paine, Mrs. F. D. Paine, R. A. Pearson, P. E.

Petersen, R. H. Porter, Mrs. R. H. Porter, A. A. Potter*, B. F. Raber, W. G. Raymond, C. E. Reed, H. A. Rice, C. R. Richards, W. J. Risley, F. A. Robbins, Mrs. F. A. Robbins, J. E. Robertson, W. S. Rodman*, A. R. Rohrer, W. B. Russell, W. T. Ryan, Mrs. W. T. Ryan, Daniels Scoates, G. C. Shaad, A. Shane, S. C. Shipley, Mrs. S. C. Shipley, F. H. Sibley, S. L. Simmering, P. K. Slaymaker, H. E. Smith, K. G. Smith, Mrs. K. G. Smith, J. E. Smith, F. P. Spalding*, L. B. Spinney, G. W. Stewart, O. V. P. Stout, I. I. Taylor, Mrs. I. I. Taylor, J. S. Thompson, F. E. Turneaure, J. W. Votey, H. W. Wagner, Mrs. H. W. Wagner, P. F. Walker*, R. S. Wallis, Mrs. R. S. Wallis, W. O. Wiley, C. C. Williams, A. L. Williston, J. F. Wilson*, Mrs. J. F. Wilson, W. M. Wilson, Mrs. W. M. Wilson, C. M. Wirick, B. H. Witherspoon, W. J. Wohlenberg (177).

MINUTES OF COUNCIL MEETINGS.

Meetings of the Council were held on June 22, 23 and 24. Members who attended one or more sessions were: G. C. Anthony, I. O. Baker, F. L. Bishop, G. R. Chatburn, C. L. Crandall, H. T. Eddy, R. H. Fernald, C. S. Howe, J. F. Hayford, M. S. Ketchum, A. Marston, D. C. Miller, W. G. Raymond, C. R. Richards, F. P. Spalding, F. E. Turneaure, P. F. Walker and W. O. Wiley.

The important motions passed were as follows:

1. That the report of the Committee on Committees be adopted. The report recommended:

(*a*) That a standing Committee of Committees be formed.

(*b*) That the Committee on Committees is to consist of the officers of the Society and two members appointed by the President.

(*c*) That the Committee on Committees is to determine what committees are to be formed to make the work of the Society effective and what specific work is to be assigned to each committee for the ensuing year.

(*d*) That committee work is to be regarded as continuous and that it is not necessary to make a final report on every topic at the close of the year, if more time is necessary to complete the work in a satisfactory manner.

(*e*) That a historical statement, an analysis of the problem, a systematic arrangement of data, and a bibliography of the subject be included in the report as their needs may appear. The diagrammatic representation of facts is to be used as far as practicable.

(*f*) That wherever possible a report should result in the formulation of conclusions to be presented to the Society for adoption.

(*g*) That in sending out questionnaires to the members, the facilities of the Secretary's office are to be used to aid any committee in its work.

(*h*) That the members be requested to make suggestions of topics to be investigated by the several committees of the Society.

2. That the Nominating Committee report, and the election of officers be held at the business session on the morning of Wednesday, June 23.

3. That the Secretary appoint an Assistant Secretary.

4. That the book value of the PROCEEDINGS from 1893 to 1900 be wiped off the assets of the Society, with the exception of the thirty-one complete sets.

5. That the Executive Committee bring in a report providing for the revision of the rules relating to honorary members of the Society.

6. That a letter ballot be taken, amending the Constitution with effect to members in arrears.

7. That it was the sense of Council that this regulation be strictly enforced.

8. That the selection of the 1916 meeting place be decided by Council after the meeting.

The following applicants were recommended to the Society for election and were duly elected: W. G. Allee, A. C. Baebenroth, H. C. Bartholomew, W. A. Bevan, R. M. Bird, M. F. P. Costelloe, J. B. Davidson, E. V. Floyd, J. S. Grasty, E. D.

Hay, C. E. Hewitt, L. C. Hodson, D. E. Lynch, J. R. Macarthur, C. C. Morris, F. H. Newell, O. A. Olson, W. E. Patten, H. J. Plagge, B. F. Raber, M. B. Robinson, J. E. Walter, M. P. Weinbach (20); Carnegie Institute of Technology.

The following budget of income and expense for the coming year was reported by the Executive Committee, and adopted by the Council:

Estimated Receipts.

From back dues	$1,000
From current dues (individual)	4,600
From current dues (institutional)	490
From advertising	1,000
From sale of publications	200
Total	$7,290

Estimated Expenses.

Annual meeting (Ames 1915)	$ 300
PROCEEDINGS:	
Printing, paper, comp., P. W., binding, packing alterations, mailing, drawing and engraving	1,500
BULLETIN:	
Printing, paper, comp., P. W., alterations, author's and editor's, mailing, drawing and engraving	1,850
Committee expenses	150
Treasurer's honorarium	300
Secretary's honorarium	1,000
Assistant Secretary's honorarium	600
Secretary's clerical assistance	600
Sundry printing	200
Postage and expressage	400
Telephone and telegrams	25
Office supplies (for all offices)	200
Total	$7,125

COUNCIL LETTER BALLOTS TAKEN DURING 1914–15.

September 24, 1914.—L. J. Beaver, F. A. Clark, H. G.

Carter, E. C. Gee, T. F. Hickerson, Wm. F. Hogg, C. E. Speirs, L. H. A. Weaver (8).

October 30, 1914.—E. C. Barton, A. F. Barnes, S. L. Brown, L. A. Doggett, J. J. Doland, C. L. Eckel, P. S. Emrick, Carl Crandall, F. A. Wirt, J. B. Morrill (10).

January 11, 1915.—D. W. Blakeslee, Rolland Adelsperger, W. P. Augel, H. E. Dyche, F. A. Foraker, P. J. Freeman, R. W. Goddard, H. J. Goulding, F. V. Larkin, Wm. A. Luby, J. H. Parkin, W. P. Powers, H. A. Vanderbeek, Erich Hausmann, D. W. Crawford, G. W. Case, J. C. Shutt, S. A. Smith, C. B. Stanton, J. M. Stetson, E. B. Waite, S. R. Wing, H. J. Wolf, L. C. McCandliss, S. B. McCormick, G. B. McNair, J. S. Mathewson, H. B. Meller, R. L. Morrison (29).

March 1, 1915.—T. R. Agg, C. H. Ashton, Hugh Brodie, F. L. Brown, C. W. Coppersmith, L. O. Grondahl, J. D. Garver, G. Goldsmith, Chas. Hancock, R. S. Hawley, P. P. Henshall, L. G. Hoxton, F. E. Jones, C. A. Johnson, J. S. Lapham, S. W. Munn, W. C. McNown, J. L. Newcombe, C. S. Nichols, J. A. Northcott, H. A. Roberts, W. S. Rodman, Thorndike Saville, A. H. Sluss, J. B. Straw, M. F. Trummell, F. A. Thomson, Purdue University (28).

March 16, 1915.—W. F. Allison, C. L. Cory, C. L. Dawes, J. A. deTurk, R. W. French, H. H. Khachadoorian, F. W. Krotzer, R. C. Lye, R. R. Martel, B. L. Remick. F. H. Stevens, H. A. Stringfellow, E. Dean Tanzer, I. I. Taylor, University of Virginia (15).

April 29, 1915.—L. D. Arnett, C. E. Barba, F. D. Crawshaw, H. R. Dougherty, F. A. Dragoun, S. L. Galpin, J. E. Kirkham, R. H. Porter, R. L. Rockwell, Kansas State Agricultural College (10).

May 10, 1915.—G. E. Bray, W. S. Gearhart, Thornton Hayes, F. D. Paine, F. F. Piper (5).

TABLE OF MEMBERSHIP.

Members July 1, 1914:	
Individual	1,353
Institutional	48

Members elected by letter ballot to July 1, 1915:			
Individual		102	
Institutional		3	
Members elected at the Ames meeting:			
Individual		23	
Institutional		1	
Total		129	
Names taken from list:			
Resignations:			
Individual	58		
Institutional	3		
Dropped for non-payment of dues	9		
Deaths	8		
Total	78	78	
Net gain		51	51
Total membership July 1, 1915			1,452

MINUTES OF THE MEETINGS OF INSTITUTIONAL DELEGATES.

The organization meeting of the Institutional Delegates of the Society for the Promotion of Engineering Education was held on Tuesday, June 22, at 4:45 P. M. The meeting was called to order by Vice-President C. Russ Richards, who said:

"It was with great reluctance that I accepted the appointment to preside at the meetings of the institutional delegates. It was with reluctance because of the fact that the University of Illinois, of whose Faculty I am a member, is not an institutional member. About a month or six weeks ago the Secretary, Dean Bishop, wrote me, asking if I would arrange a program for the meetings. It seemed an easy task when I accepted the commission. As I thought it over and attempted to outline a program which would be profitable I found it less simple.

Institutional membership was proposed and provided for at the Minneapolis meeting of the Society two years ago. The former Secretary, Professor Norris, was, I believe, the one man who was most interested in the proposal to provide for this new grade of membership. There were certain arguments in favor of such membership presented at the meeting, and yet I think few of us have a very clear conception of the advantages, purposes or aims of institutional membership.

In giving attention, then, to the organization of a program for these very brief meetings which have been allotted to us, I finally concluded that perhaps two short papers would bring before us the essential features of the institutional membership and the institutional delegate. Consequently, I undertook to enlist the support of some men who might prepare these papers. It seemed to me the first subject which might properly be discussed at these meetings would be the purpose and value of institutional membership—to attempt to get a rather clear record, if possible, in the minutes of the Society regarding this matter. I do not think there has been any definite statement regarding the purpose and value of institutional membership. It seemed to me that the second subject to be discussed would be the duty of the institutional delegate. As I thought over these subjects, it occurred to me that they were topics which should be presented by college presidents, as they are the men who determine whether institutions shall become members, and also designate the institutional delegates. Theoretically, if institutional delegates are to perform any serious function, they will report to the presidents of their colleges, something of the work and activities of the Society. I, therefore, wrote to a number of college presidents, and I found none of them were willing to respond. They apparently had no conception of the purpose and function of an institutional member or delegate. It was then up to me to get these papers elsewhere, if possible. I, therefore, called on Professor Norris, who was responsible for this institutional membership, and Professor Chatburn. Professor Norris responded with a paper on the value of institutional membership, and Professor Chatburn with a paper on the duty of the institutional delegate. With your permission I will read the paper Professor Norris has prepared.

Institutional Membership in the Society.

The plan of inviting institutions to join the Society as such in addition to their indirect membership through members of their faculties was independently suggested by the Committee on College Administration and the Secretary at the Minneapolis meeting. After consideration by the Council the decision was reached to take the steps necessary to permit such membership. This was done in regular form and nearly fifty institutional members were enrolled during the year following. At the Princeton meeting many of these were officially represented and two meetings of the delegates were held.

The primary purpose in initiating institutional membership was to bring about a closer relation between the Society and the institutions in order: (1) that the results of the Society work might be brought more directly to the attention of the teachers and administrative officers who were not in touch with it; (2) that the institutions might be brought to look upon the Society as their servant in matters affecting the general educational welfare; and (3) that the publications of the Society might be freely distributed in college libraries and administrative offices in order that they might be easily available for reference.

The theory was that a delegate would be selected to represent an institution with the explicit or implied understanding that he would go to the meeting with a sense of responsibility for getting out of it all that it contained for his institution, and that he would see that the lessons of the meeting were brought to the attention of the proper persons on his return. The general principle seemed to be recognized as correct as was evidenced by the large enrollment of institutions, and the delegates to the Princeton meeting in general expressed hearty approval of the plan.

The delegates came to Princeton with only a general idea of what their functions were but they earnestly desired to take something home that would be of service and would justify their appointment to the honorable posts which they occupied.

The delegates first had to "find themselves" which they endeavored to do at a preliminary meeting at which they discussed points such as those mentioned above. At a final meeting they discussed the lessons of the convention in a way that was most helpful and inspiring. They presumably reported the meeting to their respective presidents, being provided, about midsummer, with proofs of the parts of the September BULLETIN containing the minutes of the meeting. There was evidence during the year that the delegates were heard from in their home institutions.

Some fear was expressed at first that the delegates would form a clique within the Society, making an undemocratic division of the membership. This idea was promptly dispelled when the purpose of the institutional representation was explained. As the delegates had no power to commit any institution to any action it was plain that they had no functions besides those mentioned earlier. What they were appointed specifically to do any member could have done before and undoubtedly a few did. The meetings of the delegates were open to all. There was nothing, therefore, to cause the formation of a clique.

No very remarkable results were to be expected from institutional membership. The most that could be expected was a more immediate application of the results of the meetings and a more general appreciation of the Society on the part of college faculties. It is difficult to define the effects of membership of a college in the Society as a college in addition to personal representation through faculty members, but I claim that there are such effects. Official recognition of the Society enhances its standing with individuals. Familiarity on the part of administrative officers with faculty problems promotes a spirit of coöperation. Recommendations of the Society are bound to have more weight with member than with non-member institutions.

The institutional membership fee was made nominal in order that it would be plain that individuals were not trying to force the financial burden onto the college treasuries. And even with this low fee, three full sets of publications were to be furnished so that the general and technical libraries and the president's office might be supplied.

My suggestions for the gatherings of the institutional delegates at Ames are these:

(1) That reports be heard from last year's delegates, verbally or by letter, stating frankly what have been the results of last year's institutional representation;

(2) That some discussion be had on the topic "What an Institutional Delegate Can Do for His Institution";

(3) That the delegates consider what subjects could be taken up by the Society which would help the institutions as such;

(4) That, at the closing meeting (as last year) the delegates bring out those points and lessons which can be most profitably carried back.

The time available for the meetings of the delegates is so short that an elaborate program is undesirable. If but two or three useful suggestions are received by each delegate the effort will have been worth while.

HENRY H. NORRIS.

In the discussion of institutional membership at the Minneapolis meeting, the impression was left that institutional membership might lead the institutions to send official delegates to these conventions and to pay the expenses of these delegates; and it was urged that in that way there would always be a representation on the part of the different institutions of the country."

DISCUSSION:

Dean F. L. Bishop: It might be interesting to know that a number of institutions have sent delegates to this meeting at the institutions' expense, and a number have written with regard to this matter saying that hereafter this item would appear on their budgets. It is quite a strong movement on the part of educational institutions.

Dean P. F. Walker: It seems to me there is considerable importance in this movement that will make it worth while to continue this form of membership, and it appeals to me that we may, if we wish, proceed to make these conferences of real value. I believe that the subject of research is sufficiently recognized in our schools with reference to the bearing of research upon educational problems, that it is one topic we might discuss with some profit. I, therefore, make a motion that we lengthen the time allowed for these meetings. The motion being regularly seconded was put to a vote and carried.

WEDNESDAY, JUNE 23.

The second meeting of the Institutional Delegates was called to order at 11 A. M. by Vice-President Richards, who said, "On Tuesday we listened to the reading of the paper by Professor Norris on 'The Value of Institutional Membership.' This morning we are to hear a paper by Professor G. R. Chatburn on 'The Duty of the Institutional Delegate.'"

THE DUTY OF THE INSTITUTIONAL DELEGATE.

BY GEORGE R. CHATBURN,

Professor of Applied Mechanics, The University of Nebraska.

The writer is under the impression that one of the principal objects of institutional membership is to interest the presiding officers of colleges and universities in the affairs of the Society for the Promotion of Engineering Education; and that under normal conditions these officers would be the institutional delegates. If the president, or officer corresponding to the president, finds it inconvenient to be present the delegateship would naturally fall to the dean of engineering. Now, it would hardly be appropriate for the writer, who holds but an ordinary professorship, to explain to these high dignitaries their duties when acting as institutional delegates. Any such intention is hereby abjured and those august personages may, if they desire, close their windows and draw their blinds while this paper is being read. The chairman very frankly told me, when he asked me to write upon this subject, that he had sought diligently for a bigger man than I for the purpose but without success; no college president would undertake the task. Therefore in tendering to me this great privilege, while he did not say so, no doubt, he had in mind the adage, "Fools rush in where angels fear to tread." So this effort in compliance with the chairman's request to write a very short paper on "The Duty of the Institutional Delegate," it should be remembered, is directed simply to those who do not bear exalted titles.

In mentioning the duties of the institutional delegate it has seemed to me best to arrange them under three subheads: before, during and after the annual meeting; and to give them somewhat categorically, leaving the discussion largely to others.

Before the Annual Meeting.

To familiarize himself with the needs and desires of his own institution. He will thus be enabled to know to which portion of the program and to what other things he would best give especial attention.

To familiarize himself with new methods and practices in his institution, and, if possible, with new ideas in the minds of the faculty members even though they have not been put into execution.

To use his influence to secure papers for this Society by having those responsible for these ideas, methods and practices to write them up for the benefit of the society as a whole.

To bring before his own faculty, and especially the local members of the Society, questions of policy and interest to the general Society. Such for example as those sent out by Secretary Bishop to the several members of the Council.

During the Annual Meeting.

To observe carefully the program and take notes of those papers and discussions of interest to his own institution.

To attend the meetings of institutional delegates, lending aid and information to his fellows and deriving aid and information from them.

To present to the Society pertinent ideas and practices of members of his own faculty, providing they are not otherwise presented. These should be clearly and concisely set forth. A few well-chosen words are better than many scattered and rambling.

To ascertain through conversation and otherwise the practice of other institutions regarding questions under discussion during the year in his own.

To extend his acquaintanceship and note especially the personality of men available for positions in his own institution.

To represent generally his own institution as an attorney by looking after its interests whatever they may be and whenever and wherever deemed necessary.

After the Annual Meeting.

To make a brief report to the administration of his institution, touching in a general manner the most salient features of the convention.

To make at the opening of the fall term a more detailed report to his engineering faculty at a meeting called for that purpose. If other members have attended he could very properly assign to them separate parts of the convention to cover, thus a more interesting symposium could be held. At such time or times discussion should be elicited on the ideas brought from the convention, thus fixing in the minds of the non-attendants thoughts and methods advanced for the betterment of instructional, laboratory and administrative work. Such meetings might well grow into a local chapter of the Society, as has been the case at the Kansas State Agricultural College, for the purpose of reviewing the BULLETIN and PROCEEDINGS and discussing the papers appearing therein. Perhaps stated meetings of a faculty would be advantageous in other directions.

To represent during the school year following the annual meeting the general society in his own institution. He being the person to whom the officers of the Society could turn for information concerning, or to whom they might send information for distribution to that institution.

To furnish news items, or procure someone else to furnish them, to the Bulletin. Short notes on methods, devices and kinks are always acceptable to the editors and interesting to the readers.

To bring the general Society as fully as possible before the faculty of his institution by calling the attention of non-members to articles in the *Bulletin* or papers in the PROCEEDINGS which might interest them.

To encourage members to attend the annual meeting by bringing back to them its enthusiasm and showing them the advantages both to themselves and the institution of attendance.

It is not thought that the preceding includes anywhere near all the duties of an institutional delegate. One mind could scarcely in a short sitting, or even in several sittings, hope to gather together all things pertaining to the subject. However the above may serve as a basis upon which to start the discussion.

PER CONTRA.

Last year, on the porch of the commons at Princeton, the writer remembers overhearing a discussion in which one side contended that institutional membership was the entering wedge of trouble. That it would mean a division of the Society into classes and cliques. That the harmonious and splendid democracy of the past twenty years of the Society's history would be broken down; and in its place we should have patricians and plebeians, nobility and commonalty, masses and classes, aristocrats and democrats, *haut monde* and *hoi polloi.*

If this should be the case, that recognizing institutional delegates as different from the ordinary members will create caste, then it may be the duty of the institutional delegate to shrink up into such a fine point that he could only be seen with a microscope.

DISCUSSION.

President C. S. Howe: When I was asked by the president of the society to open the discussion on the subject of the work of institutional delegates I begged to be excused. This was partly on account of the pressure of the duties and partly because the status of the institutional delegate had never been defined and I was at a loss to know what to say. I did not feel sure that the institutional delegate had any particular function. Since coming to this meeting I have modified my views to a certain extent at least. The members who come to these meetings on their own initiative are interested in discussing those questions which refer particularly to their own line of work or the work of some other professor. Sometimes it is true that questions of general college interest are discussed and some of the papers of this character have been of very great interest and value. As a rule, however, the ordinary member represents himself and no one else. The institutional delegate, on the other hand, represents the institution and should, therefore, be interested in those broader questions which have to do with the college or department as a whole rather than with the special questions which interest the individual professors. There are many questions of policy which every institution is interested in and which it would be well for this society to discuss. They have to do with the relation of the departments to each other; the general principles which should hold in regard to courses of study; the results which may be expected from a given arrangement of studies; the relation of the engineer to the public, the relation of the engineering college to the academic college, etc. One might name a very large number of subjects which would come under this head.

The college professor is apt to be rather narrow in his views in regard to some of these questions. I think I may say this freely because I was a college professor for more years than I have been a college president. This state of mind is but natural because the college professor is necessarily more deeply concerned with his own department than he is with anything else and he does not have time to consider the relation of the several departments to each other as does the man who is forced by circumstances to consider all departments in their relations to each other and to the institution.

I would not have the institutional membership, however, limited to presidents and deans. It would be a splendid thing if the majority of the members were college professors who would thus be forced to give consideration to the more general questions which I have mentioned. The more the professor can be interested in broad questions of college policy the better it is for the college. At Case School of Applied Science we have a committee on policy, made up of the heads of departments which graduate students. Every general question of policy is discussed by this committee before it is carried into effect and I should hesitate very much to institute any policy against the advice of this committee. I hope the number of the institutional memberships will increase and that we shall have every year a large attendance of institutional delegates. I believe these meetings will give a new life and a new interest to the society.

Dean G. C. Anthony: Although the idea of the institutional membership did not appeal to me previous to the Princeton meeting, I am thoroughly convinced that it will be a most important medium for extending the influence of the Society and coördinating our work with that of the institutions represented. I believe that much of the present success is due to Professor Jacoby, who was then Vice-President of the Society. He arranged the schedule for the meetings and presided at them.

The delegate from Tufts was Professor Conner, assistant professor of civil engineering, and he presented a very comprehensive report covering most of the details of the meeting, presenting it first to the president of the college, and later to the engineering faculty. This has since been published in the BULLETIN of the Society.

The formality of the appointment of a delegate by the college, and especially the defraying of his expenses, carries with it obligations which should insure much more than a perfunctory attendance at meetings and enable the influence of the Society to permeate the faculty of the school represented, as was the case at Tufts. I do not believe that it would be wise always to consider the dean of an institution as the logical representative, but the delegate should have a general knowledge of the administrative details of his college, and its needs. His duties should be clearly defined and should include the reports to his president and faculty. I think, too, that he should, if possible, express the spirit of the meeting, if it is sufficiently distinctive to be indicated.

It is unfortunate to have this meeting of delegates conflict in any way with the regular meeting, and I hope that this work of the Society may develop into a separate section with independent aims.

I believe that institutions should defray the expenses of the delegates, as has been done in the case of the representative from Tufts at this and the Princeton meetings, since it will increase their interest in securing the full benefit which should be derived from such representation.

Dean J. H. Leete: Owing to the fact that many of us are interested in the papers which are being presented at the general session, I suggest that hereafter the meeting of the institutional delegates be set at a time which will not conflict with the general session.

Professor C. E. Magnusson: An institutional delegate of this Society is to be compared with the section delegate of the American Institute of Electrical Engineers. I would suggest that a delegate get instructions from the faculty of his institution before going to the meeting, and that topics for faculty discussion be culled from the meeting for use at the institution.

Dean Calvin H. Crouch: I have been much interested in the remarks of several of the speakers, especially those relating to the expenses of the institutional delegates which are borne by

Library
N. C. State College

the institution represented. I infer from the remarks that there is a wide difference in the practice of different institutions in this respect. I was interested in learning that some institutions defray all of the expenses of their delegates while others pay nothing. I believe a discussion of this subject or statements of what the various institutions are doing in this respect, would perhaps be valuable, as the discussions might perhaps be used advantageously by those representing institutions which pay nothing toward defraying their expenses. It is possible that some institutions hesitate to pay anything toward defraying such expenses because they do not care to establish a precedent or because they do not know the practice of other institutions.

If an institution derives any benefit from having a delegate at such a meeting as this, then it would seem but fair for the institution to stand a part of the expenses of the delegate. Just what proportion of his expenses should be borne by the institution and how much by the delegate is an open question about which there might properly be a difference of opinion, but it would seem that an institution would be justified in defraying at least a portion of the expenses of its delegate to this meeting.

Inasmuch as I was interested in learning what several institutions were doing in this respect, it occurred to me that others might be interested in learning what the practice of the University of North Dakota is in this respect. I am not aware that the University has any definite policy in regard to such matters but in several instances where it was thought the University was sufficiently interested to have a representative, the University has paid a portion of the expenses of the delegate, an amount sometimes equal to the car fare, the portion borne by the University varying with the benefits anticipated from having its representative at the meeting. I believe it is the policy of the institution not to defray all of the expenses of such a delegate for it is thought that the delegate derives some benefits from attending such meeting and should, therefore, bear a portion of the expenses. As regards this meeting the University agreed to pay an amount not equal to the traveling expenses but sufficient to encourage one to accept the appointment as a delegate and attend the meeting.

Dean P. F. Walker: I wish to say a word relative to two matters affecting the type of organization which might be decided upon. A point which has been mentioned is that a delegate in session might give time to discussion of administrative matters at the several institutions. This would seem to call for delegates who are either administrative officers in the schools, or others who are close to those administrative officers. Another idea which has been presented is that in order to advance the interests of the Society at the several institutions, delegates should be chosen with the view of interesting different members of the faculty by making possible their attendance at the annual meetings. These two ideas conflict in some degree, and it would seem necessary that we should give consideration to them.

In order that we may proceed without delay in the determining of these conditions it seems to me wise that a committee should be appointed to consider all the questions which have been under discussion and report at the next meeting of delegates. I, therefore, move that a committee of three be appointed by the Chair for the purpose of formulating plans for work and recommending a form of organization, this committee to report at the next meeting of delegates. This motion being seconded was put to a vote and carried. The Chair then appointed P. F. Walker, chairman, O. V. P. Stout and G. C. Anthony to bring in this report.

THURSDAY, JUNE 24.

The final meeting of the Institutional Delegates was held at 4 P. M., with Dean Anthony in the chair. The meeting was held at this time because of the necessity of cancelling the

Friday meeting, in order that some of the delegates might leave on the noon train.

Dean P. F. Walker read the following report:

The Committee appointed to recommend a form of organization and a general outline of the duties of delegates, begs to report as follows:

1. That the delegates constitute a committee of this Society and that the President shall appoint one of the Vice-Presidents to act as Chairman. The Chairman may appoint a secretary and a sub-committee. (We leave the matter there with the word "may." We are not ready to advise at this time as to whether we should have a separate secretary, or whether the work may all be done through the Secretary's office, without inconvenience.)

2. The delegates in attendance at any meeting shall continue as members of the committee for one year thereafter, or until their successors have been appointed by the heads of their respective institutions.

3. This Committee shall give consideration to all matters pertaining to engineering education as may be referred to it by the Committee on Committees.

4. The Committee shall meet in special session at times provided by the Program Committee in charge of the annual meetings for the discussion of all matters coming properly before it. At any such meetings attention may be given to such matters pertaining to general policies of engineering schools as may be considered by it to be appropriate. When these discussions lead to the formulation of suggestions or recommendations to the several institutions the matter shall be reported to the Council, and any such suggestions or recommendations presented to the Council are to be in the name of the Society.

It is further recommended that the Secretary of the Society inform the several institutions that it is the desire of the Society

(*a*) That when possible, each institution should be represented by its administrative head;

(*b*) That when the administrative head is unable to serve he should appoint from the engineering faculty, a representative who is conversant with the general policy of the institution and that such representative might properly be either a teaching or an administrative member of that faculty.

It is recommended also that the Secretary of the Society send to each institution a statement of the duties of the delegates as outlined at this meeting.

The main purpose shall be to consider the means for extending the influence and helpfulness of the Society through institutional membership.

In view of the fact that it seems best to defer formulation of a statement of duties of delegates until the Chairman has had time to secure written reports from the individual delegates, no further recommendations as to specific lines of work during the coming year are made at this time.

Under the direction of the Chairman of the Institutional Committee, and with the coöperation of the Secretary, copies of the two papers read will be sent to each member of the Society and it is expected in this way to receive statements of the duties of a delegate. These could be then reduced to a definite statement of the duties.

This report having been regularly moved, seconded and put to a vote, was received and adopted as read.

Discussion.

Dean C. L. Cory: I should like to ask one question, and make one suggestion. I understood, as the report was read, that there was to be sent to the several institutions represented here, certain information with reference to this Committee. I merely ask this: to whom will it be sent? To the president of the university, or to some other person?

Dean F. L. Bishop: The Committee on Committees decided, I think, that the delegate should be the official representative of the Society at the institution for the coming year.

Dean Cory: I would suggest that it would probably be covered somewhat better if this were done; that the official documents should go to the heads of institutions, but that the men sent as delegates should receive copies of all these papers. In that way we are covering it somewhat more completely. There is just one more thing. It seems to me it would help to add to the number of institutional members, if something of this kind were sent to all the institutions covered by the membership to show the intention of this Committee of the Society.

Dean Bishop: The Committee on Committees, I believe, has assigned to the Committee on Statistics the problem of determining just exactly the schools and institutions from which we shall secure data as to the institutional members, etc. Dr. Mann stated yesterday that there were possibly one hundred and twenty or twenty-two institutions in this country that might be classified as engineering schools. If we are to carry on the work of this Society effectively, in gathering information along different lines and in preparing it, we should have a specific list of institutions. We could send to this list all the information necessary and gradually more institutional members would be included. I should like to emphasize the thought that in sending out this information to institutions, it is rather important to send it to someone who is interested in the work of the organization. In many cases the president's office would pigeonhole it, and it would get no quick response.

Professor G. R. Chatburn: It seems rather a significant coincidence that the Committee on Committees and this organization should have decided on exactly the same thing, and, therefore, it augurs as a good omen. You will remember that one of the duties of the institutional delegates, which I outlined for you, was that the institutional delegate should be the official representative of the institution after the meeting and until his successor was appointed. I think he is the one who should receive all communications pertaining to this committee. If it is thought wise to send it also to the president of the institutions, that should be done.

Professor C. E. Magnusson: Did the Committee on Committees consider whether the institutional delegates might be members of the Council, or should they be separate? You might have practically two committees of the same men. with only a few additional men here; while if they could be kept separate, in cases where an institution is represented by a man in the Council, they would have two men here. Was that considered or would it be of importance?

Dean P. F. Walker: I would say with reference to that point that it seemed almost impossible to control it. We felt that this one point here was quite important; that word should be gotten in some way to the president or chancellor of the institution that, when possible, his institution should be represented by him at the annual meetings. If you put that up first to the president, as a matter of courtesy, because the institution as a whole holds the membership, then it seems almost unnecessary to advise him that if he cannot serve as the delegate, he should appoint someone else.

Regularly moved, seconded and carried that this report be transmitted to Council as a recommendation of the committee.

There being no further business to come before the meeting, the balance of the time was devoted to discussing the impressions made upon the different ones present, by the convention which was nearing a close.

Professor Chatburn: As I have been somewhat on the inside, I want to say that to me the principal thing I have noticed is the change that is coming over this organization. Heretofore we have devoted our time largely to the reading and discussion of papers brought in by the members. Now a different feeling is coming over the organization, in the appointment of the Committee on Committees, and this Committee in a way outlining to the several other committees what they want them to bring in next year; so the idea will be that in the program for the following year there will be probably fewer papers, but more committee reports. The work of the committee during the year will be largely devoted to finding out what is the present practice in the various institutions in the country along certain specific lines.´ It would seem as though we are going toward the point where we can do something definite, and where this organization will have more influence in the institutions of the country.

Professor R. H. Fernald: To my mind, one of the greatest features of this organization, in which it may not be dissimilar to others, is the question of fellowship—an admirable spirit of coöperative helpfulness which we get by talking together and getting acquainted with each other, as we have common problems all over the country. To my mind, along with that which has just been suggested with regard to committee reports, it would seem to me that possibly a little more opportunity might be given for an informal getting together, which would, perhaps, be as helpful as the presentation of so many papers on subjects which can be read and can be taken up at other times. I was thinking of suggesting at the Council meeting tomorrow, the question of the wisdom, especially for these papers that are printed in advance, of having them reduced to a ten-minute abstract, instead of giving thirty or forty minutes at a regular session, to their reading. This seems to me unwise. I believe there would be livelier discussion and better response if some such action were taken. What we need is an informal getting together, discussion and getting acquainted.

Dean Bishop: It might be interesting to remark here that we have half a day's session less this year than heretofore. That has always been a very strong part of this Society's work.

Dean C. H. Crouch: I want to speak about one other point which it seemed to me that this body might take up. Oftentimes in various institutions—I know as to this in our institution—they think they want to change something, or want to investigate some point by themselves. If the institutions knew that there was a big body, an organization like this, in excellent position to investigate, and having investigated is able to give its report big backing, this knowledge would have considerable weight with the authorities. They would decide then to wait until this body takes action before they take what might prove to be premature action. I feel, as Professor Fernald does, that the association we get here, the mixing, the talking over our troubles, problems, and so forth—that this is really a large part of what we get in such meetings.

Dean G. C. Anthony: I have personally felt a sort of undercurrent going through this meeting, a stronger current than ever before, a feeling that we were doing something besides teaching facts to students. I think it has been brought out quite strongly this afternoon, but I have noticed it from the first. I wonder if those of you who were at the Princeton meeting noted also, that there is less of the spirit of unrest here that prevailed at Princeton. I have not felt that at all at this meeting.

TREASURER'S REPORT FOR 1914–1915.

To the Society for the Promotion of Engineering Education:

The Treasurer would respectfully report the condition of the Society's finances as follows:

COMPARATIVE BALANCE SHEET 1913–14 and 1914–15.

Assets.

Accounts Receivable.	1915.	1914.	Increase.	Decrease.
Back dues	$ 607.72	$ 279.54	$328.18	
Current dues	1,389.04	1,055.22	333.82	
Advertising and publications	279.90	419.46		$139.56
Cash Lincoln Tr. Co	654.64	1,340.59		585.95
Dean Bishop	100			
Union Sq. Savings Bank	383.68	371.05	12.63	
Inventory of publications	4,047.50	3,937.55	109.95	
	$7,462.48	$7,403.41	$784.58	$725.51
			725.51	
			$ 59.07	

Liabilities and Surplus.

Accounts Receivable.	1915.	1914.	Increase.	Decrease
Accounts payable*	$643.96	$250.00	$393.96	
Dues non-members	3.50	26.90		23.4
Members dues paid in advance	43.74	103.85		60.11

* There are outstanding accounts for which bills have not been presented. As far as the Treasurer's accounts are concerned such become payable only when audited.

Surplus	6,387.60	6,651.61		264.01
Life membership	383.68	371.05	12.63	
..	$7,462.48	$7,403.41	$406.59	$347.52
			347.52	
			59.07	

TRADING ACCOUNT.

June 18/14.		
Inventory	$3,937.55	
Cost of Publication (Schedule D)	4,051.52	
	7,989.07	
Less Inventory on hand, June 16/15 (Schedule C)	4,047.50	
Cost of Sales		$3,941.57
		$3,941.57
Sales of Publications:		
Sales to members and non-members	575.09	
One-fourth of individual members' dues	1,376.00	
Three-tenths of institutional members' dues	143.25	$2,094.34
Advertising	1,195.50	
Less discount	21.03	1,174.47
Balance—profit and loss acct., loss		672.76
		$3,941.57

PROFIT AND LOSS ACCOUNT.

Balance—trading a/c	$ 672.76
Princeton Meeting (Schedule B)	426.92
Secretary's Office Expenses (Sched. E)	3,245.33
Treasurer's Office Expenses (Sched. A)	350.96
	$4,695.97
Dues, individual	$4,128.00
Dues, institutional	334.25
Discount received	56.59
Interest on bank balances	14.56
Deficit for year	162.57
	$4,695.97

BALANCE SHEET.

Assets.

Accounts receivable:		
Members: back dues (Schedule AA and FF)	$ 607.72	
Members: current dues (Schedule BB and FF)	1,389.04	
Members and non-members: Adv. and Publications (Schedule CC)	279.90	2,276.66

Cash, Lincoln Trust Company	654.64	
Union Sq. Savings Bank, Life Membership Fund	383.68	
Dean F. L. Bishop	100.00	1,138.32
Inventory of Publications (Schedule C)		4,047.50
		$7,462.48

Liabilities and Surplus.

Accounts Payable (Schedule F)	$ 643.96	
Dues, non-members (Schedule EE)	3.50	
Members' dues paid in advance (Schedule DD)	43.74	691.20
Surplus, June 18/14	6,651.61	
Less: Dues of members dropped or resigned and accounts uncollectable	101.44	
	6,550.17	
Less: Deficit for year	162.57	
	6,387.60	
Life Membership	383.68	6,771.28
		$7,462.48

MEMBERSHIP.

		New:		Res. or Dropped.		
No. of Men.		Individual.	Institutional.	Individual.	Institutional.	Total.
June 1911	1,071	114		83		1,102
June 1912	1,102	107		51		1,158
June 1913	1,158	215	44	59		1,358
June 1914	1,358	143	7	69	2	1,437
June 1915	1,437					

It will be noted that the Treasurer's accounts are kept in accordance with the following schedules, which are not printed as they are quite extensive. These schedules are kept filed for reference by members of the Society in the Treasurer's office. (AA) Back dues, (BB) Current dues, (CC) Accounts receivable for advertising and publications from members and non-members, (DD) Members paid in advance, (EE) Due non-members, (D) Printing (sundry, BULLETIN, PROCEEDINGS and reprints), drawing and engraving and editor's salary, (C) Inventory of PROCEEDINGS, BULLETIN and reprints, (B) Expenses of meetings, (E) General expenses such as postage of all kinds, telegrams, advertising of publications, expressage and freight, clerical assistance, insurance, committee expenses, Secretary's salary, etc., (A) Expenses of the Treasurer's office, (FF) Current and back dues of Institutional members.

Respectfully submitted,

W. O. WILEY,
Treasurer.

REPORT OF SECRETARY FOR 1914–15.

The growth of the Society during the past year has been normal. As a part of this report there is included a table showing the membership at the beginning and end of the fiscal year.* The large number who have been dropped during the past year is accounted for largely through the resignations of those who have joined the Society but who are not particularly interested in the work. They are mostly consulting or practicing engineers in commercial companies.

The increasing importance of the Society is well illustrated by the fact that it has been asked to be represented on various national committees, among which are The National Association of Technical Secretaries, of which the Secretary of your Society is first vice-president; The Committee of the Classification of Technical Literature, of which your Secretary is a member. The Society has also been asked to join the Pan-American Engineering Congress to be held in Washington next December. The Society was represented by the Secretary at the fiftieth anniversary of the founding of the Worcester Polytechnic Institute; at the installation of President Goodnough of Johns Hopkins University, and President Bumpus of Tufts College.

One of the notable facts of the year has been the establishment of the first section of this Society at the Kansas State Agricultural College, with Professor Conrad as Secretary. The object of this Section is the discussion of the papers appearing in the Bulletin and other subjects of general educational interest, and to submit papers and discussion to the Publication Committee for use in the BULLETIN.

Bulletin. An extra number of the BULLETIN containing the twenty-year index of the PROCEEDINGS was published in August. The work entailed on this was done at Ithaca under the direction of Mr. A. C. Stevens, former assistant to Secretary Norris, and great credit is due him for the efficient way in which he conducted the work. Very few corrections or additions have been noted.

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* See page 12.

The Publication Committee during the year has endeavored to supply college notes in each number of the BULLETIN, of general information and interest to the members of the Society. It has also endeavored to supply at least one paper in each number of a general nature on the different phases of educational work and one on laboratory work. Many of these have been illustrated and have brought forth a large amount of discussion. There are many more papers submitted to the Publication Committee than is possible to publish. It does not seem possible under the present system, to increase the size of the BULLETIN very materially. It is probable that the number of illustrations will be increased, thereby giving added interest to the papers.

The volume of the PROCEEDINGS of the present year, was edited by the former Secretary, Professor Norris, and was printed on thin paper, thus making the volume easier to handle and at the same time reducing the postage, thus insuring a considerable saving.

A small booklet was issued early in the year giving some facts concerning the Society, together with reasons for becoming a member.

The question of back dues is becoming a pressing one. It is impossible to conduct the work of the Society unless its members pay their dues promptly. Most of these amounts arise from negligence. While it is a very small item to many members, the total is a very large item to the Society.

The Special Membership Committee appointed from institutions west of the Mississippi River and Illinois and Wisconsin, consisting of Deans Stout, Shenehon, Richards, Walker, Richter, Covell, Spence and Professor Spalding, have done excellent work in increasing our membership from those institutions.

F. L. BISHOP,
Secretary.

ADDRESS OF WELCOME ON BEHALF OF THE IOWA STATE COLLEGE.

BY RAYMOND A. PEARSON,

President of the College.

President Marston, Ladies and Gentlemen: I sometimes think an address of welcome is superfluous. If there is one place where the old adage, "Actions speak louder than words," is true, it is on an occasion like this. But I shall go through the formality of saying how welcome you are here. We are very glad to see you. We consider it an honor to have you with us. Our committees have been working hard for some weeks in anticipation of your coming, and we sincerely hope that you will find things here to your liking, comfortable and convenient, so that when you go away, you will look back upon this meeting as one which was well arranged in advance, in so far as the institution itself could do these things. I hope none of you will have occasion to reflect upon the meeting as a friend of mine did who attended a convention in a small city some time ago. The rates at the hotel were two dollars on the second floor and two dollars on the third floor; and during the week of the convention there was a special rate of two dollars on either floor.

As everyone of you knows, this is the land-grant institution of the State of Iowa. This Institution, in common with others of its kind, has been experiencing a considerable growth in student enrollment in the last few years. I am going to take a few moments of your time to tell you something about the college, not that I think you do not know about it, for many of you are connected with other land-grant institutions; but here you are, on this ground, and I shall give you just a few of the high points, if you like.

Our total student enrollment last year, excluding summer session, was over twenty-seven hundred. About twenty-three hundred of these were in collegiate courses, the remainder being in what we call sub-collegiate courses. Students may be admitted to the sub-collegiate course if they have not finished the high school, though they must have finished the grammar school. The four hundred sub-collegiate students were mostly in agriculture, though some were in short courses in trade school work where we are preparing young men to take places as stationary engineers, and positions of that character. Of the nearly twenty-three hundred students in the four-year courses, about half are in agriculture, and the majority of the balance are in engineering. There are between seven and eight hundred in the collegiate and sub-collegiate engineering courses. We have about six hundred students in home economics, and about one hundred each in veterinary medicine and in science as applied to the industries.

The student enrollment in the last two years has increased practically seven hundred—the exact number is 681—mostly in the four-year courses. This increase is largely in agriculture and home economics. The engineering attendance has decreased year by year recently, as has been the common experience throughout the country; but the tide has turned and the enrollment this year is the largest in our history. Engineering attendance is again on the up-grade; and perhaps we are doing pretty well when I remind you that there is also a strong engineering college in the State University at Iowa City.

In addition to our collegiate and sub-collegiate work, we operate experiment stations in agriculture and engineering, and we are carrying on investigations in reference to animal diseases. Then, too, we are conducting extension work and this state has been generous in respect to this work. Last year the state gave $90,000 for extension work in agriculture and home economics. Recently we have started extension work in engineering. This includes short courses held in different parts of the state, somewhat along the lines developed in Wisconsin.

We have at this institution profound respect for the engineer and we have a great desire to promote his interests and the interests of engineering in all its aspects. Our lines of engineering instruction are the usual lines,—civil, electrical, mechanical, mining and chemical and ceramics and recently we have established two new departments, transportation and structure design.

We think that here, more than at some of the older institutions, the value of the mental training which engineering courses offer is appreciated. We believe that for the average young man who is going into general life work, a course in engineering gives better mental training than a course in liberal arts. In saying this, I do not exclude liberal arts *in toto*, because a certain amount of that work properly is a part of an engineering course. We have here occasionally a student taking engineering preparatory to becoming a lawyer. I think this is a good fundamental training. A leading lawyer of the State had just finished work on an important case in which a great railroad system was involved with heavy damages claimed. The lawyer had on his desk a pile of engineering works and he said to me, "I would give a good deal if I could have studied engineering in place of some other things."

We emphasize another point; that engineering has value from the standpoint of culture. We have heard that farmers and engineers are not cultured. We do not believe this and will not accept a definition which necessarily carries this meaning. In our opinion, a man is cultured if he is a gentleman and can go into a community, mingle with the people and command their respect, because of the knowledge which he has and because of his ability to enter into their affairs, to see things from their standpoint and to talk with them intelligently. Then, where would engineering instruction have greater value from the cultural standpoint than in this state, or in the country?

We say to the young man in agriculture that if he really loves electricity, it may be of more cultural value to him to take a study in electrical engineering, perhaps wireless telegraphy, than to take one of the old-line cultural subjects which he dislikes. In compelling him to take the latter, we might emphasize his dislike for it. Rather than do that, we would let him take the work in wireless telegraphy, and later depend upon him to develop, in his own way, some of the other general knowledge in the useful liberal arts subjects. Likewise we say to the engineering student that if he truly likes horses, there is no reason why he should not take a two or three-hour study on caring for or judging horses.

But our great work here is along the old engineering lines. Development in this state as does the development of the country, largely involves the problems of agriculture and engineering. Here in Iowa we are producing crops valued at nearly half a billion dollars a year. We have already put in underdrainage—I think I am correctly informed—to the value of about one hundred million dollars. It is an engineering proposition and they tell me the work is only well begun. We have enormous natural resources which must be developed with the aid of engineers. Twenty-five years ago, many of my classmates in engineering in Cornell University were looking forward to going into railroad engineering. At that time railroads were being built rapidly. I suppose no state is better supplied with railroads than Iowa; they are located everywhere here because of the flat character of the country and because there is business in every part of the state. Nowadays, railroad mileage is not being increased very much, but we continue to need engineers to maintain and improve the railroads. We need other engineers to develop the state. There are large mining interests in Iowa. Our clay deposits are large. At a single point in the state the clay products shipped out amount to some trainloads daily. This is one of the great clay centers of the United States.

I must mention a hobby of mine: I am expecting the engineers to develop a natural resource, the wind. I refuse to believe that that greatest natural resource is going to remain useless for all time to come. One of our earliest graduates, Dr. La Verne Noyes, of Chicago, a man who has won great success in the manufacturing field, largely because of his investigations of and manufacture of the wind mill, is responsible for the statement that enough wind blows through a square rod to furnish all the power, heat and light on an average farm. Gentlemen, I am going to put that proposition up to you. We want the wind harnessed here in Iowa. If you could feel that resource as we do occasionally, you would appreciate better what I am saying.

Again, I bid you welcome. We feel honored; we feel flattered by your coming here; and we want to do everything we can to help make this the best meeting that this very useful Society has ever held.

RESPONSE ON BEHALF OF THE SOCIETY.

BY GARDNER C. ANTHONY,

Past President of the Society.

President Pearson, Ladies and Gentlemen: I find it very pleasant to perform the task which has been assigned me, of saying a word in response to President Pearson's welcome. It is a double pleasure, first, because of the warmth and genuineness of your welcome, second, because you represent a section of this country which has been productive of the highest educational development and intellectual vigor. I say this section, instead of speaking of it as the West, because, although this is my "farthest West," in using that term I have always met with the response, "but this is not the West, you must have come from the Atlantic seaboard." Your institution lies in those meridians from which I have personally drawn the greatest inspiration, and to which I send all good men in the educational field who need to breathe the air of freedom in educational life. An eastern man, as I am, having great reverence for the institutions of the East, recognizing fully their value, and knowing that yours are built on their foundation, yet I believe you have added something to education that they never would have had; and I am profoundly grateful for it. It seems to me that one of the very important phases of the work of this Society is to bring more of that freedom into the East, especially to the Atlantic seaboard.

Finally, I thank you very much for the hearty welcome you give us, for the cordial invitation you extended to us last year at Princeton, and for its realization here.

ADDRESS OF WELCOME ON BEHALF OF THE STATE OF IOWA.

HON. A. B. CUMMINS,

U. S. Senator from Iowa.

Mr. President, Ladies, and Gentlemen of the Society: The task that has just been so graciously assigned to me by the President of your Society is peculiarly agreeable to me. It is agreeable for two reasons, at least: First, because to exercise for a moment the functions of a host is always delightful, and second, because of the very nature of things. I am relieved now of the heartbreaking and soul-crushing responsibility of attempting to say anything that will add to the sum of human knowledge. It seems to me that I have been speaking continuously for more than twenty years; and I have learned how much greater is the capacity of man to speak than his capacity for thought. The truth is that I have in all these years grown gray-haired in the effort to express a substantial uniformity of idea in a complete variety of phrase. Just at this moment, however, I am conscious of but one embarrassment; and it arises from the doubt I honestly entertain with respect to my ability to subordinate a long-continued habit to a firm and worthy resolution. For some years now I have been a member of a legislative body. Its members agree that it is the greatest legislative body in the world. That sentiment, however, is not universal. However that may be, this great body has but two methods of bringing debate to a close—that is to say, of terminating talk. The first is by unanimous consent. It is rarely given. The other is through physical exhaustion. It never occurs. The members of that exalted tribunal constantly exemplify one mighty ambition. It is, that they may make their utterances immortal by making them eternal.

You can understand, therefore, with what trepidation I arise, encumbered with a habit of this sort, and whether I can escape its influence on this occasion remains to be seen.

I think I have a fairly good title to exercise the very honorable, enjoyable position which my friend, the president of your Society, has just conferred upon me. I believe that I have some title to speak for Iowa and to interpret her thought. Nearly fifty years ago I was admitted to the membership of her citizenship. I think I may speak in a sense for your immediate host, the Iowa College of Agriculture and Mechanic Arts. For more than seven years I was a member of the board of trustees of this institution, and learned to admire it, learned to hope for it, as I learned to admire and hope for no other institution in all the land.

Professor Marston said that I have a right to speak as an engineer. Well, it is true that for two years in my early life I was a little bit of the ragged fringe of the noble cloth of your learned profession. I have a mind to tell you about that experience, if you will allow me to drop into the first person, and to indulge in a habit that only the old can safely enjoy, the habit of reminiscence.

I came to Iowa when I was a boy of nineteen. I had left college; that was all. I thought I was master of myself and master of the conditions that might confront me, but I soon discovered that I was mistaken. It was not three months until I was working at a carpenter's bench at one dollar a day. I enjoyed it, of course; it was my trade and the trade of my father. I graduated into the express office at McGregor, where I helped a great corporation to distribute, not its dividends, but its trade; and shortly after that I was offered a position as assistant county surveyor in Indiana—Fort Wayne. I had a smattering of mathematics in school, and I accepted the position. I filled it, how well I do not know. The surveyor himself was at the time division engineer on a railroad that was being constructed from Fort Wayne to Richmond, called the Cincinnati, Richmond and Fort Wayne Railway.

After I had been wandering over the swamps of the Maumee, for some months hunting for lost corners with all the zeal and industry I could summon, the engineer came to me one day and said, "I want to come back to the office, and I want you to take my place on the railroad." He had charge of about seven or eight miles then in course of construction. I said to him, "I can't do it; I know nothing about civil engineering." I knew nothing of it save the little glimpse of a great field I had received in my four years in school. "Oh, yes," he said, "you'll have no trouble whatever."

Now, I pledge you my word that I had never had a transit in my hand. I had never seen a level. The road had been located, and was just at the point of construction. The particular division to which I was finally assigned had never been cross-sectioned, although the grade, fortunately for me, had been laid upon it. I remember, as though it were yesterday, the day I left Fort Wayne, trundled down through the swamps of Indiana, and finally reached the headquarters of this particular division. There I found a body of four or five men, who were supposed to be my subordinates, who were supposed to accept or to receive orders from me with regard to what ought to be done; but there wasn't a one of them who did not know infinitely more than the man who came to command and direct them.

I slept at a farmhouse that night, our headquarters. I told the boys that I would give them a holiday the next day. That was not entirely unselfish; for there was a part of the road already built, and I spent the next day, the first day I was filling this position, walking over the part of the road that had been built, so that I could see how a railroad embankment was made, and how a railroad cut was made; so that I could once glimpse a railroad culvert, and see in a general fashion how the thing should be done. I returned, and the next morning I shouldered my level and started out. I tell you, I had never had any acquaintance with that instrument before. I shouldered that level, and took those men, and went to work; and through the providence of things—I don't know how it happened—I succeeded in finishing the cross-sectioning of that division.

It was not long after that until I was taken to Portland, into the office of the chief engineer, or the assistant chief engineer. In a few months he was appointed chief engineer of the T. A. B. & N. Railway, and the directors of this company, in the bliss of their ignorance, selected me as assistant chief engineer. In those days it was not as it is now, when all the plans for all the culverts are uniform, and the bridges are planned in the central office, and explicit instructions sent out. The engineer in those days had to make plans for every culvert and for every bridge, for turntables and for station houses. I shall never forget as long as I live my embarrassment when it first became my duty to make a plan for a water tank. Why, I had never seen a water tank, let alone design one. I went from Portland to Ridgeville, fifteen miles away, to see a water tank, as I would have gone to see a monument of architecture.

Somehow or other that road was finished, and the next year it came about that I was offered a position upon the Northern Central Michigan, a road running from Jonesville to Lansing. It was my duty to locate that road; but I had become by that time an accomplished engineer, and I did locate the road. It was then that I discovered for the first time some of the intricacies of railroad building. This railroad was under the auspices of the Lake Shore and Michigan Southern Railway, but was constructed through the agency of a local company. The local company had entered into a contract with a minister, who had for the time being turned himself toward commerce and industry, and he was to grade the road for the local aid. The company had secured a local subsidy, and notes had been contributed by the citizens along the way, who wanted additional commercial facilities. The first real difficulty I encountered was the insistence of the contractor who was in charge of the work that I should do what he suggested;

that the road should be so located, the grade so established, that he would be able to make something out of the contract into which he had entered. It never seemed to concern the people in those days that in future times a heavy grade might increase the cost of operation, or that a sharp curve would accomplish the same purpose. I refused to yield to the contractor's demand, and although he may have known more about it than I, I insisted upon locating the road and establishing the grade that seemed to me would best answer the necessities of transportation. I was immediately haled before the board of directors and in the issue between me and this preacher-contractor, I was easily defeated. It was his interest that established the grade, and it was his welfare that determined where the road should go.

I quit civil engineering. I got just that glimpse of it, however, which enabled me then and enables me now to understand the nobility, the greatness, the worthiness of the profession of which you are members.

I welcome you most heartily to this commonwealth. Fortunately, one can speak in praise of his own State without disparaging any other. I believe that the star which shines for the State of Iowa in the blue field of Old Glory shines with a little steadier light than that which emanates from any other star in that wonderful constellation. Iowa has a great many things of which her people are proud, but the chief of them all is the character of her men and her women; the best and most enduring of them all is the disposition of the citizens of the state. I dare to say that in all the round of commonwealths, there is no state in which the problems of government are so simple as in the state of Iowa. There is no community in all the world, two millions and one half in number, so deeply law-abiding, so devoted to all the principles of exalted government as the two millions and one half, or nearly that, who compose the citizenship of this state. We have no great cities. I live in the largest city in the commonwealth, and it is a village of one hundred thousand people. Our population is rural; our interests are generally disseminated. We have no men or corporations of great wealth, but the average wealth of the people of Iowa is two and one quarter times as much as the average wealth of the people of the United States, and it is more than the average wealth of the people of any other state in the Union.

I mention this because I am part of it, and because I want you to know it. We have here 57.000 square miles of territory, and 97½ per cent. of it is susceptible of profitable cultivation, and 94 per cent. of it is at this moment under successful cultivation. There is no other such fertile field in all the world. You cannot find 57,000 square miles of the earth's surface anywhere the world round, of which so large a proportion as I have just named can be used in agriculture. It naturally follows that Iowa has a greater volume of agricultural products than any other state in the Republic. It follows that, acre for acre the state over, our farms are worth more than the farms of any other state in the Union. There may be better land than ours, but there is no state which approaches this one in the value of its farms.

Moreover, Iowa—and this touches engineering—Iowa has more miles of railroad according to its area, or according to its population, than any other state in the Union. It has more colleges according to its population than any other commonwealth.

I have mentioned these things, not at all to suggest any invidious comparison with any other commonwealth. because I know there is no state but in some respect lifts itself up above all its fellows. I have mentioned them because I want you to know that in the great mass of civilization, in this mighty age of progress, this community is doing what it can to render a good account of itself and of its people in the day of final reckoning.

Moreover, I will not say that of all the agricultural or scientific colleges of the land, that of Iowa is the best. That would be clearly invidious and discriminating. But I want to say of this institution, of which you are now the guests; as my friend George W. Perkins of New York said the other day, in a speech in Philadelphia, of the United States Steel Corporation and the International Harvester Company. "These are not monopolies; oh, no. These great commercial and industrial institutions are simply eminent in the fields which they occupy"—so I say of the Iowa State College: it may not be the greatest, but I can confidently claim that it is eminent, if not preëminent, in its field. What I really mean is this: I am better acquainted with the work of this institution than I am with the work of any others. I know more of what it has done for us than I know of what your colleges in other states have done for you; and I would be false to my devotion to this institution if I were not to say that I think the Iowa State College has done for the people of its state more in developing the love for and heightening the dignity of agriculture; has done more to enroll the farmer in the ranks of the learned professions than any other institution throughout the whole country.

That is the great value, after all. I know there are institutions that in science, in the development of science, in research, in all those abstruse things, have possibly outreached our own. But something has endeared this institution to the farmers of this state. I think it has ennobled the work of the farmer, dignified it, and I am thoroughly sincere when I say that I think it has lifted them into the ranks of the learned professions. For nowadays a farmer has to be an engineer. I do not know what you will call him finally, what kind of engineer you will call him, but the day is rapidly dawning when the people who till the soil, and do it successfully and in competition with their fellows throughout the world, must be engineers in all that the name implies. And I think they are rapidly becoming so here.

Iowa welcomes you most heartily, and before I say a parting word, may I not congratulate you upon a thing that is foremost in my mind and that is closest to my heart. I cannot in these days confront an audience of my fellow men and women without congratulating them upon the profound peace which now blesses the republic of the United States. To me, we seem to occupy not only a unique position in the history of the world, but we occupy a most fortunate attitude toward the most appalling disaster which ever fell upon mankind. I would not stay the progress of this occasion a single moment upon this subject, were it not that I believe that you are shortly to confront the most serious responsibility ever encountered by the American people. I do not believe that we will be involved in the war. I cannot conceive a situation which will warrant interference upon the part of the United States in the horrible conflict now laying desolate the whole continent of Europe.

But some day peace will come; some day the nations of Europe will lay down their arms; some day the voice of civilization will be heard; some day the peace-loving people of the world will have an opportunity to make their influence felt. And it is to equip you with a full sense of your responsibility when that day dawns that I have mentioned this subject. I do not know who is to blame for the war in Europe. I do not know that the blame can be imputed to any particular nation. But I want to call your attention for a single moment to the narrowness of the issue, the miserable, trifling character of the question which finally brought down upon the millions of Europe the unprecedented calamity which is now sweeping like a besom from one corner of the continent to the other. And I do this for a purpose.

Just remember that Austria made certain demands of Servia. Servia complied with these demands, save two. These two were: first, that Austria should be permitted to enter Servia and assist the Servian officials in administering the law of Servia upon certain men whom Austria charged with being instrumental in inciting sedition against Austria, arising out of the circumstances surrounding the absorption of Bosnia and Herzegovina in 1908. That was the only question; that is, the two allied questions—should Austria enter Servia and help the latter sovereignty administer her laws; and second, should Austria be permitted to name certain officials who, it was claimed, had been guilty of inciting insurrection against

Austria? That was all. It ought to have been local. I do not attempt to say whether Austria should have made the demands or not. I am not here to insist that Servia should or should not have yielded to the demands, although to have yielded to them would have been to have surrendered her sovereignty in the eyes of the world; but that was all. Because those two nations could not compose that little issue, could not determine between themselves how Servia should bear herself toward Austria, Austria declared war against Servia. Russia, feeling that her interests were involved in the sovereignty of Servia, and in the perpetuation of the Balkan integrity, mobilized her troops; and Austria declared war against Russia because she mobilized them. Germany declared war against Russia because she was afraid the troops would pass over the German frontier. Germany declared war against France because France would not agree to remain neutral. Great Britain declared war against Germany because Germany violated, as Great Britain charged, the neutrality of Belgium.

Thus the whole of Europe, and three fourths of the civilized peoples of the world, are at war. Why? Because two countries would not pause long enough, or at least one of them would not pause long enough, that the nations of Europe might sit down calmly and discuss in an amiable way these differences between Austria and Servia. Two millions or more of men have already died in order to settle that dispute; hundreds of thousands of homes have been desolated forever; burdens beyond compare have been laid, not only upon this generation, but upon generations yet to come, because that little question could not wait a single day for adjustment and discussion.

Now, do not imagine that I forget the underlying irritation of Europe. I have in mind all the great straining desire of Russia to reach the Mediterranean and the Adriatic. I do not forget how Germany, with its vast energy, developed more rapidly in the last twenty years than any nation in the world, felt that her territory pressed hard against her beating heart I do not forget that France was resentful because in 1871 she lost two of her provinces. I do not forget the ambition of Great Britain to be eternally the mistress of the seas. But none of these things would have brought about the war. These things have lasted for half a century. They have endured in all their strength for half a century, and yet the attitude of the nations of Europe was more kindly and friendly toward each other than for years, because Great Britain and Germany came a little nearer together in the settlement of the Balkan War than they had been in more than a quarter of a century.

Do not imagine that I am saying these things in order to weigh the fault or blame that is to be attached to any nation. I am saying them simply to impress upon you my belief that the day will come when we can broaden infinitely the field of mediation and arbitration. I am opposed to war. It is an awful price to pay for anything. It is too great a price to pay for anything save human liberty. When this war comes to an end, it will be for the United States to lead the world a step in advance toward wider arbitration and more efficacious mediation. It will be for the United States at least to lead the world forward a single stride in international law. My friends, we have not made an advance in international law in more than three hundred and fifty years. The obligations of nations to each other, as expressed by Grotius three hundred years ago, are more humane, more Christian-like, more civilized, than the obligations which the nations are now recognizing as existing between each other. We have moved backward instead of forward, and we are tolerating, or observing rather, atrocities which would have brought the blush of shame to the barbarian's cheek in the darkest ages of the world's history. The United States has assumed a lofty position. It can lead the world on, and then will come the moment which will present the best opportunity citizens of the United States have ever had to bless mankind. And I hope sincerely that in this juncture—and I believe I ought to say it, because I am not of his political faith—I believe that the people of this country, without respect to party, without respect to opinions upon domestic policies, should as one man sustain and strengthen the arm of the President of the United States.

RESPONSE ON BEHALF OF THE SOCIETY.

F. E. TURNEAURE,

Past-President of the Society.

Senator Cummins, Ladies and Gentlemen: As one of the past-presidents of the Society, it seems to be my duty, and it is my privilege, to acknowledge for the Society the very kind welcome given to us by the state of Iowa through Senator Cummins. I think the time has come when I can also acknowledge the great hospitality which has been shown the Society by all our friends, and particularly by the college, by President Pearson, Dean Marston, and Dean Curtis.

It is not often that this Society meets on the great prairies of the Mississippi Valley, and when it does meet in the wonderfully rich basin of the United States, I cannot imagine a more fitting place than here at Ames. In the middle of these boundless prairies we get some little appreciation of the great riches of which the Senator has already spoken. It was quite fitting that yesterday the members of this Society should be shown over a portion of the prairies, so that we could appreciate better what you have here. I think the Senator and the citizens of Iowa need not be at all fearful of a foreign invasion of the State. If an enemy should appear at the Mississippi River, I imagine he would be made welcome and invited to beat his sword into a plowshare, to work this wonderful land. Or possibly, if the enemy appeard too fierce, the entire population of Iowa would be loaded into automobiles and taken over the backbone of the continent in forty-eight hours.

I want to congratulate, too, the Senator and the state of Iowa on the exceedingly fine College of Agriculture and Mechanic Arts developed here. I certainly agree with the

Senator in what he has said with regard to the development of this wonderful college. I believe personally, and I think it is the opinion of the Society, that in no state has the development of the education given by the higher institutions of learning fitted better the interests of the state than is the case in Iowa. I want to thank you again for your welcome and for your hospitality, and I hope the day is not far distant when we may have the privilege of coming here again.

THE RELATION OF THE ENGINEERING SCHOOLS TO THE PROFESSION, THE STATE AND THE PUBLIC.

PRESIDENTIAL ADDRESS.

ANSON MARSTON,

Dean of the Division of Engineering, Iowa State College.

For many years the world has seemed enamored with engineering and industrial education. The achievements of the last hundred and fifty years in the mechanic arts have been of such wonderful and far reaching character as literally to revolutionize the material details of life, and even of intercourse between human beings, including the interchange of thought between human intellects. It was natural to assume that modern engineering had revolutionized man himself, as well as his mode of life, and had been one of the main forces which had banished forever the bloody cruelties of the past. Deep thinking men, however, understood all along that any hundred and fifty years constitute such an infinitesimal part of the millions of years of man's past and future development as to be capable of changing his real character but a little, and that he still retains much the same savage instinct as of old. Events since the memorable first days of last August have made the whole world realize this fact. We have learned, with mingled amazement and pain, and have shown that engineering, which has so ministered to happiness and intellectual progress, has also armed that fierce creature man with new weapons of unheard of frightfulness, certain to be used in the ruthless killing of women and children.

BROADER ACTIVITIES OF ENGINEERING SCHOOLS.

Industrial and engineering education have now arrived at a point where, in order properly to fill their functions in the scheme of the world, it becomes necessary to enlarge their activities to include directly the uplift of man. The engineering schools must deal directly with the industrial world, the engineering profession, the state and the public, as well as with their immediate clientage of students.

"Engineering is the professional phase of mechanic arts." "The mechanic arts are those arts which are characterized by applications of the science of mechanics." "The engineer is the man who *directs* mechanic arts work."* Engineering is thus vitally connected with all mechanic arts industries, and engineering education with industrial education.

Engineering schools ought to take a broader view of their functions than has hitherto generally prevailed. They ought to fit themselves into a carefully planned system of industrial education, and to accept responsible duties of leadership therein.

Engineering educators ought clearly to recognize that engineering and industries are not in themselves ends but merely means to a great end, namely, the end of promoting the happiness, the welfare and the uplift of the world. An ingenious harvesting machine is of little worth in itself, but of much as a powerful agency in feeding the hungry. A great bridge is of note only as it represents the fruition of faithful effort and of genius, and as it lightens the task of the citizen and facilitates the intercourse of the world.

Engineering schools do not fulfill their duties by the training of "efficient" engineers alone. Human machines are but a step higher than machines of iron. The real object of the engineering schools is to advance engineering science, and so to disseminate engineering knowledge throughout the world as thereby to increase production, to diminish its cost and the cost of distribution, to promote health, convenience, safety and enjoyment, and to educate and protect every citizen in all his rights which are in any way affected by engineering principles or practice.

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* From definitions by a committee of three college presidents, four deans and one professor of engineering, and the United States Commissioner of Education. See *Proceedings Land Grant College Engineering Association,* 1914.

There are those who, naturally if superficially, would blame the European war upon our modern engineering and industrial education and system, saying, with a recent magazine writer,* "Militarism is the militant factory. The factory—by factory I mean of course our whole industrial system—is our educational system at work." Even to such critics the remedy is to broaden rather than to curtail industrial education. "We are ready to supplement manual training with man training," says the same writer.* On the other hand the bitterest accusers of Germany recognize that her wonderful strength, in peace as well as war, comes largely from her wonderful system of industrial (including engineering) education. It follows that every nation which would be a strong nation must develop industrial education effectively to develop national strength.

Thus from two widely different points of view comes strong additional support for the conclusion that our engineering schools, as our inherited leaders in industrial education. must now face wider duties than ever before recognized, and must even assume vital responsibility for the continued existence of democracy itself. Can a democratic country, without adopting militarism either in law or in spirit, develop a complete system of industrial education and organization, which shall reach effectively every workman, in fact every citizen? If our engineering schools cannot successfully serve as leaders in solving this great problem, then inevitably they must be deposed from leadership.

The Profession of Engineering.

We have inherited too narrow an ideal of the engineering profession. There was a long debate as to whether the engineer should be a "scientific" or a "practical" man, in which it has been decided that both sides were right. But we have never yet fully realized the fundamental error of the unconscious assumption made during that debate, that, like the doctor and lawyer, the engineer renders merely a personal service to a client for a personal fee. As a matter of fact there are fundamental differences between engineering and the earlier recognized "learned professions." It is not specially important that engineering is not nearly so much of a closed caste as law and medicine, for the engineer is bound by the same principles of professional honor, obligation, ethics and *esprit de corps* which govern and inspire the lawyer and the doctor.

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* *The Century*, June, 1915.

Engineering is the professional phase of the mechanic arts, in which arts hundreds of millions of men are engaged. These myriads are of all ranks,—unskilled laborers, expert mechanics, foremen, superintendents, engineers, masters—without separating barriers of caste.

In some important particulars the work of the engineer is bigger and broader than that of almost any other profession. In addition to rendering expert personal professional service, he must serve as an officer in great industrial and engineering organizations, striving, like the officer in an army, for the success of his army rather than his personal success. Above all, the really great engineer is the master engineer, who must have such great qualities of leadership that he can control men and capital, and organize great undertakings.

As an officer in some engineering or industrial organization it may even be the duty of an engineer to refrain from personal professional service in favor of some less qualified man. I have a friend who is a national authority on bridges and reinforced concrete, but who, as an ex-officio member of a state highway commission, finds it necessary to refrain from making plans for highway bridges, and, instead, to assist in developing a commission staff of bridge engineers, capable of doing successfully the highway bridge and culvert work for 2,000,000 people.

Confused by the custom in other professions of personal service to a client, the engineering profession has in the past made the great mistake of acquiescing as a matter of course in the separation of the master and the engineer. This mistake has worked injury both to the master and to the engineer. No master can secure the greatest results through the services of men whose work must always be to him a closed mystery. As for the effect on the engineer, the separation of master and engineer has robbed the engineering profession of its greatest birthright; for the man who hires roomfulls of engineers must always occupy to them the position of superior to inferiors.

Henceforth the engineering schools should make especial effort to inculcate the ideal of the master engineer in the minds of their students, and into the spirit of the entire engineering profession. The master engineer may be a great manufacturer; a railway president or general manager, or the manager of any great department of a great railway; he may be a state highway engineer, charged with organizing the work of hundreds of engineers and thousands of road officers in work vitally affecting millions of people; he may be the chief of a government engineering service; the promoter and developer of a great hydraulic power plant or of an interurban or street railway system; he may be a great contractor; in short, he may render any *master* service in engineering lines. The characteristics of the master engineer are leadership, initiative, inspirational and organizing ability, combined with expert engineering skill.

In all ranks, every engineer should be more than an engineer. He should be an active good citizen, and assume leadership in public affairs related to engineering. There are many who decry politics to engineers. On the contrary, engineers should take part in politics, especially where the public need information and advice on engineering questions in deciding how to vote. I would like to see engineers serve frequently as councilmen and mayors of cities, as county supervisors, as governors of states, as members of legislature and of congress. Whatever may have been true of Indians at one time, a good citizen is a live citizen.

THE RELATIONS OF ENGINEERING SCHOOLS TO THE ENGINEERING PROFESSION.

The engineering schools should maintain most active and intimate relations with the engineering profession at large, and especially with their own alumni and with the practicing engineers of their vicinity. There should be not too infrequent interchange of positions between engineering faculties and practicing engineers. There should be a constant succession of visits and lectures at engineering schools by outside engineers of note. Members of engineering faculties should, without exception, belong to local and national engineering societies, and in general take some active part in their work. Engineering professors should, as in the past, continue active engineering research, and contribute freely to engineering literature. All the above is, of course, simply a statement of accepted opinion.

The author believes that the engineering schools ought to go far beyond their generally accepted practice in affording direct assistance to practicing engineers. Every important engineering school has a large amount of costly apparatus, all of which is needed part of the time for instruction purposes, but much of which could readily be devoted for part of the time to the solution of the many special engineering problems, constantly arising in the engineering practice of any region, which are unsolvable except by the aid of engineering laboratories such as the private engineer cannot hope to possess. The engineers of a region should be able to get cordial help from nearby engineering schools in such cases.

Engineering schools, by proper extension work, can also effect much in educating officials and the public as to the nature and value of competent engineering service in connection with specific public improvements, and in many cases should formally organize for work of this character.

In this work, and in the general work of coöperating with practicing engineers, the frequent publication of bulletins on special engineering questions, part of which should be of semi-popular character, can be made of much value.

There seem to be two points of possible irritating contact between practicing engineers and the engineering schools.

First, engineers properly object to activities by an engineering school which may amount to rendering "free" direct engineering service, such as is customarily supplied by practicing engineers. The speaker has had experience with irritation caused by unfounded suspicion of a "technical service bureau," organized under his direction by an engineering extension department. The activities of such a bureau should be restricted to educational and research work. In the case mentioned the difficulty was overcome by frank consultation with the criticizing engineers.

Second, and much more important, is the puzzling question of private work by engineering professors. Practicing engineers often complain that it is unfair that they should be subjected to competition by professors, whose salaries and whose freedom from the expense of maintaining offices and sometimes even of purchasing instruments, and whose opportunity to use students as assistants at small expense, all enable them to do outside engineering work at prices below those at which a private engineer can live. The complaint is made all the more bitter by the fact that the professor often gets the work simply because of the prestige of his college position. We cannot help sympathizing with such complaints, and fees charged by engineering professors in their private practice ought to be higher, rather than lower, than generally prevail. Furthermore, students and employers of young graduates often complain that their professors who engage in outside work are thereby prevented from devoting themselves to their classes, which are often turned over to young and inexperienced assistants.

On the other hand, it is manifestly impossible to teach engineers properly without using engineers for teachers. To say that the teacher shall have no connection with actual engineering work is to say that he shall not be, or at least not remain, competent to teach engineering. Often too, the engineering professor, because of his official position, may be the only available engineer who can render the service desired.

To refuse engineering professors all chance to actually practice engineering seems really absurd. They need to do some practicing to prove to their students that they are competent.

Then, too, an engineering school not infrequently secures for its students instruction on some special branch of engineering by a man of higher grade than it could afford except by allowing him to earn part of his remuneration outside.

Outside work by engineering professors should not be forbidden, but it should be so closely regulated and controlled according to just principles as to free it from all just criticism. In formulating rules for the regulation of outside work the authorities of engineering schools would do well to confer in the frankest manner with the practicing engineers interested, both individually and through their society officers.

Regulations controlling private work by engineering professors might perhaps provide: (1) that no private work shall be undertaken of amount or character to injure college work in any way; (2) that private work will be permitted when of such character and amount as actually to benefit college work; (3) that all the circumstances of private work by professors, including the total amount, the prices therefor, and the methods of obtaining work, shall be such as not to constitute any injustice to engineers in private practice; (4) that, in order to permit proper administration, formal permission shall be secured in advance from a designated college authority for private work in each instance and permanent records of such work filed.

The Engineering Schools and the State.

The relations of the engineering schools to governmental organizations are of great and growing importance. It is easy to see that state supported engineering schools are under special obligations to the state. Even in the case of privately endowed schools, and independent of the means of support, engineering schools are such a vital part of the general educational system as to impose binding obligation to comply with the general plan.

The movement for the passage of laws licensing engineers seems bound to prevail in the end, and, if successful, would seem certain to bring about, as a corollary, state inspection and classification of engineering schools. Certainly the state has a right to demand of all engineering schools that their graduates shall be thoroughly trained and competent.

In addition, the state has a right to demand that the engineering schools fit efficiently into the general system of industrial education. In the industrial army the engineers, the professional experts, are the educated officers. Hence the engineering schools must be the West Points rather than the drill barracks, and cannot properly be trade schools, which must educate hundreds of thousands instead of thousands, and teach an elementary instead of an advanced course of study.

Trade schools, moreover, must be local in character, designed mainly for the education of boys of fourteen to sixteen years of age, living at home. Trade schools must also provide, by evening classes and otherwise, some trade education for mechanics, who in addition to living at home are also earning their livings by working daily at their trades. All attempts to develop trade schools which are not essentially quite narrowly local in character have been comparative failures, with attendance insignificant in view of the numbers needing the training. Trade school work must be carried to the workman, for the workman cannot go to a distant school.

Nevertheless the state has a right to demand from state supported engineering schools, and to expect from others whose resources permit, some active and effective assistance in educating workmen, and in carrying technical information to public officials and to the public itself. The engineering schools can render service in these lines which is beyond the resources of a local trade school.

The most effective organization for such work is an engineering extension department. An engineering extension department can assist the local trade schools by lectures and special short courses by high grade experts; can offer to mechanics correspondence courses at home under actual personal supervision by instructors at intervals; can provide "short courses" of a week or more for painters, telephone operators, carpenters, stationary engineers, and other mechanics, at which the advanced features of their trades can be demonstrated by their best trade experts; can, through a technical service bureau, carry educational technical information concerning specific public improvements directly to the officials in charge; can offer technical lectures to high school students and to the public; can provide automobile and other technical institutes at convenient points around the state; can publish popular bulletins on technical subjects of general importance; and can do much other valuable work beyond the resources of local trade schools.

Engineering schools ought immediately to begin to provide special courses for the training of teachers for trade schools, and it would greatly benefit engineering professors and instructors themselves to give them special training in pedagogy. Competent, specially trained teachers will be one of the most important essentials in the development by the state of an adequate system of industrial education.

The state has also the right to demand from state supported engineering schools effective scientific assistance in the development of its industries. Such assistance can most effectively be rendered through the medium of engineering experiment stations, devoted especially to the scientific investigation of the technical problems of their separate states. Such stations are already rendering invaluable service, which is provided for in no other way in America.

THE ENGINEERING SCHOOLS AND THE PUBLIC.

It has sometimes seemed as if there were a tendency for some engineering educators to feel that about the only duty they really owed to the public was to induce it to send as many engineering students as possible to their particular engineering schools, yet there is vital need for the widest dissemination among all the people of correct elementary ideas on engineering subjects, and for the education of public opinion to correct views on the general policies of the public and the state toward engineers and engineering. In democratic countries, and even in autocratic in the end, the public is the final arbiter on engineering as well as other questions. Whether the advice of engineers is accepted or not, and whether their services are used or dispensed with, depend ultimately on whether the public holds correct views on engineering questions. We are constantly railing at its mistakes. Why not turn in to help educate it aright?

Then, again, in many phases of engineering work the ultimate success must depend upon the engineering intelligence of the individual citizen. This is true of heating, lighting, sanitary and mechanical conveniences in the home, of machinery for the farm, of vehicles for the roads, of the use and misuse of roads, pavements, sewer and water works systems and public utilities generally. The same Mayor of Chicago who just gave such excellent service in stopping the street car strike, was reported in *Engineering News* of almost the same date to have said "We are glad to have lots of water and waste it, for it makes Chicago a cleaner and healthier city." Unfortunately there is no hope that the editorial of *Engineering News* on the utterance will be read by the citizens who control the mayor who controls Chicago's engineers.

It is the duty of the engineering schools to educate the public along correct engineering lines to the extent of reasonable possibility. Members of the engineering faculty can do something by lectures and newspaper articles. Graduates can be inspired to take active part in public discussions.

Those engineering schools which maintain engineering extension departments and engineering experiment stations can do especially effective work in the education of the public. Besides the wide distribution of popular technical bulletins, the press of the state can be utilized effectively by the systematic publication of short dispatches on engineering subjects. In the case of contemplated public improvements, addresses by college experts to meetings of citizens affected are often in much demand. A large correspondence with individual citizens on technical questions may be developed and made of great value as an educational agency.

Wider Horizons for Engineering Educators.

In this address it has been the intent to present strongly the view that the college walls of the engineering school ought to inclose the world, that the engineering educator ought to play a man's part in the wide activities of a man's world, that there will be little place in engineering education for the man or the school content with the comfortable routine of the class room and the enjoyment of scholarly retirement. Wider and more important opportunities are before the engineering schools than ever before. The very welfare of the country rests on them in important degree.

It would not be fair to present this view without saying that in the wider activities advocated much will be encountered which is unpleasant as well as much which is inspiring. The mistakes of engineering professors who take part in the wider activities will become known to the public instead of only to the president; and the institution will suffer instead of only the student. Even the best work will often make enemies. Those for whom the best work is done will often misunderstand. Selfish interests will be encountered, and will fight if the college work is really effective.

A Wisconsin university, whose professors have served effectively on many commissions, whose extension departments have taken an active part in shaping industrial education, whose faithful and effective work has aroused at the same time antagonism from selfish capital and from uninformed consumers, may even be compelled to pass through trying times of political misrepresentation, of formal investigations. But the great work she has done will stand the tests. Why should not such work be tested? Engineers specify tests.

One engineering educator engaged extensively in the wider activities, has carried in his pocket for two years the immortal words of Kipling:

If you can keep your head when all about you
Are losing theirs and blaming it on you;
If you can trust yourself when all men doubt you
But make allowance for their doubting, too:
If you can wait and not be tired by waiting.
Or being lied about don't deal in lies,
Or being hated don't give way to hating,
And yet don't look too good, nor talk too wise;

If you can dream—and not make dreams your master;
If you can think—and not make thoughts your aim;
If you can meet with Triumph and Disaster
And treat those two impostors just the same,
If you can bear to hear the truth you've spoken
Twisted by knaves to make a trap for fools,
Or watch the things you gave your life to, broken,
And stoop and build 'em up with worn-out tools;

If you can make one heap of all your winnings
And risk it on one turn of pitch-and-toss,
And lose, and start again at your beginnings
And never breathe a word about your loss;
If you can force your heart and nerve and sinew
To serve your turn long after they are gone.
And so hold on when there is nothing in you
Except the Will which says to them, "Hold on!"

If you can talk with crowds and keep your virtue,
Or walk with Kings—nor lose the common touch,
If neither foes nor loving friends can hurt you,
If all men count with you, but none too much;

> If you can fill the unforgiving minute
> With sixty seconds' worth of distance run,
> Yours is the Earth, and everything that's in it,
> And—which is more—you'll be a Man, my son!

I believe utterly in the ability of engineering educators and of engineering schools to meet fully the responsibilities and to perform ably the duties of the widest activities proper in engineering education. I believe in the numerous existence of the master engineer among engineering educators, the men of initiative, and of leadership. I believe in holding the ideal of the master engineer before the engineering educator as before all engineers.

A REPORT OF PROGRESS IN THE STUDY OF ENGINEERING EDUCATION.

BY C. R. MANN,

Carnegie Foundation for the Advancement of Teaching.

Dean Anthony has correctly stated that this is a coöperative study of engineering education. He has just been rejoicing over the fact that he has had the year off, with only one or two pleasant meetings in various places, talking over the work. I want to give warning, however, that this is only the calm that precedes the storm. For so soon as we have the material organized in a form in which it is amenable to criticism and suggestion, the committee is going to hear from us. I hope that this will be early in the fall; and from that time on you may expect a very active coöperation between the committee and the Foundation office in regard to the further development of the work.

This is a preliminary report of progress. I shall, therefore, merely describe in the briefest possible way the four lines of work that have been started, and the general indications up to the present time.

The first of these four lines deals with the origin, development and progress of engineering schools. It seems important that we should understand why it was that engineering schools, with the exception of the Rensselaer Polytechnic at Troy, suddenly sprang into prominence in this country after the Morrill legislation in 1862. Was this an unexpected growth that sprang up as it were over night? or was its advent prepared by a long series of incidents? I have been very much surprised. as the committee has been. to find that the public demand for an education for use was clearly expressed at a very early date and that it became more and more insistent as the industries of the country developed.

The first clear statement of the importance of education for use appears in Benjamin Franklin's well-known pamphlet on "The Education of the Youth of Pennsylvania," in which he urged the introduction into the schools of those subjects and methods which would conduce to the largest public utility. That the importance of practical education for all, in addition to the usual ornamental education for a few, was recognized by Washington is shown by his remarks in his message to Congress on December 7, 1796, in which he calls their attention to the necessity of action to encourage agriculture. The committee to which this suggestion was referred reported that the best means of promoting agriculture was to give the farmers the easiest means of acquiring the best information concerning the management of farms and to excite in them a spirit of enquiry, industry and experiment. In 1814 Jefferson wrote "I have long been collecting materials for the plan of a university in Virginia which should comprehend all the sciences useful to us, and none others." His plan for a "school for technical philosophy where the higher branches should be taught in abridged form to meet the practical need" in addition to the usual literary college for pure culture, was never realized.

In 1785 the Philadelphia Society for the Promotion of Agriculture was established and the Society of Mechanics and Tradesmen in New York was organized. In 1819 the New York legislature appropriated $10,000 a year for two years for the "promotion of agriculture and family domestic manufactures." The next year the Pennsylvania legislature appropriated funds for the promotion of "agriculture and domestic manufactures." In 1823 the Committee on Agriculture of the State Legislature in New York presented a fine plan for an agricultural school and urged the state of New York to establish and support it at public expense. This report outlines in detail the organization and the curriculum of the school that was then wanted; it describes fairly well the type of school which after years of experiment has eventually been evolved; thus showing that the idea of what was needed and wanted was clearly in mind as far back as 1823. One interesting point is that this report ascribes this plan directly to the Fellenberg school at Hofwyl, Switzerland. This school, you probably all know, was organized by Pestalozzi and his pupil, Wehrli. The fundamental idea of this school was that of making labor a principal means of training the young. Henry Barnard states that because of the methods developed at this school, Switzerland obtained a system of public education whose foundations were the wants of the nation; and the idea of training by productive and civilizing labor was advanced from theory to practice.

From 1823 to the passage of the Morrill Act in 1862 many organizations like the Franklin Institute, the Ohio Mechanics Institute, and various state agricultural societies were established, all for the purpose of securing more useful education. In 1837, when John Smithson bequeathed to the United States $500,000 for the "increase and diffusion of knowledge among men," several suggestions were made for the use of part of this fund for the encouragement of useful education. After nine years' consideration Congress made other disposition of the fund. Another quarter of a century had to elapse before the government recognized that the foundation of a true democracy is a system of public education which effectively meets the needs of all the people and passed the Morrill Act.

It is thus perfectly clear that the people in the early history of this country had a very definite idea of what they meant by education in agriculture and the mechanic arts and of how schools should be organized to secure it. It is also perfectly clear that when schools of agriculture and the mechanic arts were established after 1862, they did not at first succeed in accomplishing the purpose for which they were established. It is only within the last twenty years, perhaps, that the schools have really developed an organization and method of teaching that bids fair to give the people what they have so long sought in vain.

The main conclusion, perfectly evident on the face of the facts, is that the people in the early history of this country had a very definite opinion, very clearly explained in early documents, of the type of education that they wanted. The schools that were established for that purpose have achieved that ideal in a very marked degree only in the last few years.

The second line of investigation has been aimed at finding what the engineering profession wants. This has been done in two ways: first, by many personal interviews with engineers in practice and with schoolmen on the subject; and second, by sending out a circular letter, which many of you have received, asking a few leading questions. These letters were sent by the engineering societies to their membership—23,000 were sent out in all. The suggestions secured from these interviews and these letters are not yet classified. There are, however, certain ideas that occur so frequently that you cannot fail to be impressed by them even after a cursory examination.

In questioning the efficiency of the engineering schools at the present time there are four conspicuous things in which the professional men show a fair degree of unanimity. The first and most important is English. A large majority of the letters received mention the absolute necessity for higher efficiency in the training in English. One engineer states that faulty English wastes each year more money than would pay the United States debt. Engineers should be able to express their precise ideas clearly and accurately, and should be certain that their words convey to another the thoughts that they wish to express.

This criticism of English is a very far-reaching one because English depends on so many things—inheritance, home environment, youthful associations, early schooling, social opportunities, and the like. But clear expression in English depends even more on how the engineering subjects are taught. No one can express himself clearly unless he has been taught in the science and engineering departments to think clearly. No one can write a convincing report unless he has learned to discriminate between essential and unessential elements; between important and unimportant factors,—in other words, he must have acquired perspective. This problem of more efficient English involves the whole school and it cannot be effectively solved without the earnest and sincere coöperation of all the departments.

The second point which is prominent in the professional criticism of engineering schools is the engineer's breadth of view. The present importance and the rapidly expanding scope of the engineering profession demands men with vision, enthusiasm, and sympathy,—men with ideals and faith in human nature. At present, public service commissions are usually composed of lawyers, men of business, perhaps doctors and possibly theologians. These men make the general plan for new roads and decide which road shall be improved first to meet the social needs of communities. Then engineers are employed to do the technical work of construction. Men of broader social outlook and broader appreciation of human relations lay out the larger plan; the technical details are too frequently the sole inheritance of the engineer.

A large majority of the practicing engineers suggest that the kind of breadth that is wanted may be developed by more study of sociology, economics, history, psychology and ethics, rather than by the usual haphazard efforts at securing some knowledge of foreign languages. A reading knowledge of French and German does not seem to be essential for the engineer, although some still cling to the old ideas of the efficacy of mere language study in developing culture. Spanish may be more desirable because of its utilitarian value.

The third important point in the professional criticism is the lack of what they call business sense. They do not expect the student to know the exact prices of cast iron or brass per pound; but they do want him to know instinctively that if he figures the cost of forty tons of cast iron at two million dollars something is wrong with his calculations. It is a sense of relative values that seems to be needed. A competent engineer is not a man who can design a bridge, but a man who can design the best bridge for the least money.

The fourth and perhaps the most important point on which many members of the engineering profession agree in criticizing the schools may be called over-specialization. Some state it by saying that there is too much specialization with a consequent lack of thoroughness in mastering fundamental engineering science. Others describe it as a failure to be able to apply general principles to practical problems. Too many technical details are taught, and too much time spent in describing industrial methods many of which are obsolete and all of which can be learned better after the student begins the particular practical work which he happens to take up after graduation. One well-known engineer and teacher quotes Huxley in explanation of this point as follows: "The knowledge I have looked for was a real, precise, thorough, and practical knowledge of fundamentals; whereas that which the best of candidates, in a large proportion of cases, have had to give me was a large, extensive, and inaccurate knowledge of superstructure."

These four points present the more comprehensive problems now facing the engineering schools as seen by those who have the opportunity of observing the way in which graduates function in practice. There is a vast amount of detailed suggestion in addition, but these leading ideas may serve to give some notion of the attitude of practicing engineers toward this second part of the study.

The third part of this investigation consists of an analysis of the work of some of the schools. I now come to the subject of classification, mentioned a little while ago. We are making no effort to classify engineering schools in any way, shape, or manner. This is a study of engineering education. We are trying to measure the efficiency of the current methods of instruction for educating engineers, and are not particularly interested in the classification of the schools.

I have already visited ten schools, spending from three or four days to two weeks at each, have interviewed the members of the family very carefully, studied their texts, their notes, their examination papers, the records of the schools, etc.

One general method of analysis of the school work has turned out in practice to be very illuminating. This method was suggested by Dean Anthony in Boston one night last fall, when he said he had noted that in his school students in engineering did not do as good work in the second year as in the first, and he wondered why it was. He said other schools had noticed the same fact. About that time Mr. Humphreys, of the Massachusetts Institute, published his studies of the standing of students at that school, showing again that students make a lower average grade in the second year than in the first. The records of ten schools have been analyzed formally, and several others informally, and they all show the same drop in average grades in the second year.

As an example of the method we have selected five well-known and typical schools for presentation here. The average grades of the members of the graduating class for 1914 are as follows:

School.	Freshman.	Sophomore.	Junior.	Senior.
I	74.5	72.0	70.0	71.5
II	66.8	64.7	65.6	64.0
III	76.1	73.4	75.5	74.0
IV	79.6	77.0	77.3	87.3
V	67.0	65.2	68.2	

The average curve for these five schools is

Freshman.	Sophomore.	Junior.	Senior.
73.2	70.4	71.3	74.2

In order to discover what caused the sag in the second year, a note was made of every subject in which any student made a low record. Where the school rated students on the *A, B, C, D* scale, marks below *C* were considered low. Where a numerical scale was used with 60 as the pass mark, records below

70 were noted. When the pass mark was 70, records below 75 were noted.

The following table gives the number of students who had one or more low grades in the subjects specified. In all, 220 student records are here summarized.

Subject.	Number of Students Having Low Grades.	Percentage.
Physics	114	52
Mechanics	99	45
Foreign language	91	41
Calculus	79	35
English	78	35
Chemistry	46	22

All the other subjects in the curriculum have some low grades but none of them run over 5 or 10 per cent. All the above percentages would be higher if schools that grade on an *A, B, C, D* scale discriminated between a high *C* and a low *C*.

These figures show that the schools themselves realize that even the proficient students who are on the whole considered worthy of graduation have not done good work in physics, mechanics, foreign languages, calculus, English and chemistry, These subjects are the fundamentals on which the superstructure of engineering ultimately rests.

These facts present a very interesting problem. I am not yet prepared to give any answer to it. This is the situation, and if you will study your own records, you will, I think, find it is a fairly good summary of the general conditions. There are, of course, variations in the various schools. But we are not interested in the personal characteristics of the different schools or of the different departments in those schools; we are interested in the general problem, and this represents the general situation fairly accurately. I am glad to notice that we are to hear from the committees on teaching physics, on teaching mechanics, and on mathematics, and perhaps they will tell us how to cope with these conditions.

Whatever the recommendations of these committees may be, it is perfectly clear to all that there are as many different methods of teaching as there are schools. This is evident also from the fact that the percentage of students who have low grades in physics varies in the schools studied from 14 to 62. This variation is due to so many individual and local causes that no one is willing to draw the conclusion that a low percentage means a high efficiency in teaching. Yet some less personal and more positive means of measuring teaching efficiency should be possible. The ordinary examination does not do it; is it not possible to find something that will?

Again, the figures given above are compiled from the records of those who graduated. They show the subjects in which the more competent students had difficulty, but take no account of the low grades of those students who were eliminated because of poor work. Yet in engineering schools in general about 50 per cent. of the entrants are eliminated before graduation. This indicates an enormous waste, both for the students and for the school, and shows clearly that the sorting out process at admission has an efficiency of only fifty per cent. It seems as if it ought to be possible to devise more efficient methods of finding out whether a boy shows promise of engineering ability. Engineering is a rather positive, definite thing, and it should be possible to find out by tests of one sort or another whether the boy really ought to study engineering or not. You *do* find it out in three or four years, but then there has been enormous waste. You should be able to find it out right away, when the boy presents himself for admission.

Another important problem is that of measuring the efficiency of the school as a whole. This is a complicated problem because certain schools get a higher type of material at entrance. They develop these young men in a particular way and they go out and make a great success. Other schools receive rather crude raw material, and though the product may not make so great a success, the school may have done more for their development than did the other type of school. It is hard, then, to say how much of that success is due to the innate ability of the students and how much is due to the training they receive at the school. It seems to me conceivable, at least, that we might devise methods of measuring accurately how much of a student's progress is due to the school.

In order to assist the schools in making a more successful choice of material at entrance and in measuring more definitely the efficiency of the teaching in developing engineering ability, we have secured the assistance of Professor E. L. Thorndike, of Columbia University, who is conducting elaborate experiments in testing engineering freshmen and graduates. We have also organized a small committee consisting of three well-known engineers, Professor Thorndike and myself, for the purpose of planning, discussing and criticizing these experiments. We expect that this work will result in establishing types of tests that will enable the schools to increase their efficiency both in selecting the students for admission and in measuring the contribution of the school toward the progress of those students.

In brief, then, the work of the joint committee during the past year has been organized on the general plan of furnishing the schools with: (1) A history of their origin and development. (2) A statement of the professional demands they are trying to meet. (3) An analysis of their present conditions and methods of work. (4) A method of measuring their own efficiency in the admission and development of students. This is intended to give the schools a more definite conception of their purposes and ideals, an increased appreciation of the importance of a continuous scientific study of their own educational methods, and a more positive and objective method of measuring their own results.

DISCUSSION.

Professor W. S. Franklin: I would like very much to suggest to Professor Mann that he endeavor to devise a form of test which I have been trying to devise for two or three years to enable one to determine whether a student makes any progress in his ability to *realize* the physical things he studies about in the text and in the classroom. My belief is that there is not a single definition in physics, which when you reduce it to its simplest form does not become an *actual physical operation*, something done with the hands.

Dr. C. R. Mann: Two of the tests of the Columbia freshmen were specially devised to measure mechanical sense. In one the student was given a box with five compartments. In one compartment there was a piece of harness put together in the right way, and also the loose pieces required to make it. A second compartment contained two ordinary door-locks, one in proper form and the other in parts. Number three contained in like manner two snap switches: number four contained two clockworks, and number five had two electric pull sockets. These mechanical devices are arranged in the order of difficulty of putting together. The test consists in seeing how many the student can put together in one hour, beginning with the simplest. A boy of fine mechanical ability does the five in fifty minutes. One who is clumsy at it succeeds in doing only one or two in the hour.

The other test for mechanical sense consists in asking the student to execute practically with simple apparatus a series of projects such as lowering the pitch of a tuning fork, measuring the pressure of the gas at the tap, connecting up an electric bell so that when the circuit is closed it taps instead of buzzing. These projects again are arranged in the order of difficulty. The mechanical sense of the student is a function of the number he successfully completes in an hour.

President C. S. Howe: Sorted them out in regard to what? I am much interested in that, because the ability to do the things Dr. Mann has mentioned depends largely upon the previous education of the boys. If they came from technical high schools they would do them rapidly, while perhaps boys from the classical high schools—many boys do go from classical high schools to engineering colleges—would have had no experience in these things. So I am anxious to know what it is you are trying to test.

Dr. Mann: We were trying to test whether they saw physics in physical things, or saw it only in an abstract way. We want them to see these things not as abstract things, but as physical things.

President Howe: The two sets of boys would not be put on the same basis by that test, on account of the previous education they have had. It seems to me the one boy may have had these very things in his high school and, therefore, he does them naturally and easily because he has had the practice; while the other fellow would not know how to do them. That would not be a test of the fellow's natural ability to do the thing.

Dr. Mann: All the boys had had one year of high school physics. They were selected because they came from schools which keep careful records,—from six high schools in the immediate neighborhood of New York. Two cases in particular I might mention. There was one of these students of engineering who was rated very high by the college and the high school instructors on the basis of their personal observation; he was rated very high too by his classmates. His general school record was also excellent, yet he could not do a single one of the mechanical tests, but was the top man in all the English tests. So he switched over to the School of Journalism. Another man who was unknown to the class generally—his classmates did not know him well enough to rate him—who had poor records in the college, made the best record of all in the mechanical tests. We found afterwards that he was working fifteen or twenty hours a week outside in practical work.

President Howe: I was going to say that the Binet tests have been very severely attacked by Dr. Ayres of the Russell Sage Foundation of New York because they do not take into account the training of the boy before he has taken these tests. It seemed to me, after reading Dr. Ayres's criticism, that the Binet tests would have to be modified if they are to be used by educators in the future.

Professor Frederic Bass: I would like to ask if these students were subjected to repeated tests of this character, so that the effect of practice in solving them could be traced?

Dr. Mann: I can answer that very simply. We began work last February. The tests were begun in the middle of April. That was the first experiment. We devised a series of tests which seemed reasonable to us, and we tried them on one group of thirty-five boys. We are not going to publish any tests until we have tested them carefully. A great many other trials must be made before it will be possible to determine to what extent these tests may be relied on as measures of engineering ability. The determination of their correlation factors will require a large amount of careful experimental work. The important thing is that the schools become interested and undertake this sort of experimentation themselves.

As this work progresses and is carefully checked up, the dependability of the tests becomes greater, so that eventually we may develop a series of tests of real value. Even in their present experimental condition, the tests already tested are a great improvement on the ordinary examination system in speed and definiteness.

Professor Franklin: I think Dr. Mann has not understood the kind of test I had in mind. I remember many years ago putting a student to work one afternoon to detach a mercury filament of prescribed length in the testing of a thermometer. The directions placed in his hands were those given in Kohlrausch's wonderfully clear book. All he had to do was to read a sentence then do what that sentence said he was to do; then go on to the next sentence, and so on. Each of these sentences was as clear as it could be, and yet that young man worked for three solid hours and did not get even the first operation done. I then took the thermometer in my hand, made a few movements, and he said, "Oh, is that what the book means?" One thing physics teachers are trying to do more than anything else is to lead young men to understand what they are talking about when they talk to them. That is the biggest difficulty; to have them really understand language which does not refer to love stories.

Professor R. H. Fernald: I want to touch upon one or two points in connection with Dr. Mann's discussion.

Regarding the meaning of grades, I desire to say that an important factor which, I believe, Dr. Mann should take into account is the instructor. It seems to me Dr. Mann needs some fundamental test for the professor in order to get his viewpoint; that is, what the professor is trying to do and why he is trying to do it.

The product produced in any institution will, to a certain extent, be affected by the attitude of the man in charge of the work. If the figures, which Dr. Mann has presented, include any of my records his deductions would, I believe, be modified if he knew under whose jurisdiction the grades were given for the different years as different professors have totally different points of view regarding the value of marks. For example, I seldom give a grade corresponding to "Distinguished." I usually use only the grades meaning "Passed" or "Not Passed." In some cases, I use a grade that corresponds to "Good."

I learned, just the other day, that the students in my department had received no honors because no grades of distinction are given. If the granting of honors is an important factor, my viewpoint regarding marks might be changed as several boys might receive grades indicating "Distinguished" if I felt that honors were vital. The grades in the department over which I preside run rather low as a whole in the third and fourth years as compared with the first and second years, when most of the work is not of a professional character and does not come under my jurisdiction. All these points should, I believe, be taken into account, as I feel, as indicated above, that the grade is, to quite an extent, affected by the purpose and attitude of the man who gives it.

Referring to another point, I understand Dr. Mann to say that through some of his tests he hopes to show whether or not a young man will make a good engineer and what field of engineering he should enter. If instead of saying that the tests will show whether or not a man would make a good engineer, Dr. Mann would say that the tests may show whether or not a young man should take a certain course in engineering, I could, I believe, feel more assurance in the results of his tests because I believe that many a man who would not make a good mechanic may make a good engineer and vice versa.

One of the best engineers I have ever turned out showed no ability as a mechanic. He apparently never had any, but I recommended him without hesitation for exceptionally good engineering positions. Why? First of all, he had received an A.B. degree before taking his technical work. He was also a mighty good all-around gentleman. I doubt, however, whether, if Dr. Mann's tests were applied to him at the time he began his technical work, he would have been advised to take a course in engineering. To repeat, if Dr. Mann says these men should not take certain courses or work in certain fields of engineering, I can see possibilities from his tests, but to broadly say these men will not make good engineers is, I believe, a little beyond the possibility of such tests at the present time. Further than this, many men take engineering courses who have no idea of being engineers. I graduated two boys this year who took the work merely because they believed engineering courses provided good fundamental training for them. One is to follow law as a business but wants engineering as a foundation. The other has personal affairs to attend to which have no bearing on engineering but he believed the discipline and training of the course to be good as a general preparation for life. Either of these men, so far as general capacity goes, would make good engineers. I am wondering, therefore, whether such points were considered by Dr. Mann's committee.

Dr. Mann: If I might reply to Professor Fernald, I would say that it is very important, if you wish to make scientific studies of grades, that a finer differentiation of grades be made than is done in your institution. If you use only two grades, passed and not passed, the students are merely divided into two heterogeneous groups which give little information about their different grades of ability. There should be at least three grades above and one grade below the passing mark. Otherwise you can not arrange the students in the order of their ability.

The other point, as to sorting out engineers, is a question of vocational guidance with which we are not concerned at present. All we hope to do now is to point out a way in which conditions may be improved by reducing the present outrageous mortality of fifty-four per cent. to a much more reasonable figure. We are trying to find a positive way of getting at definite information that will enable you to lower that percentage.

THE EDUCATION OF THE FUTURE ENGINEER.

C. L. CORY,

Professor of Electrical Engineering, and Dean of the College of Mechanics, University of California.

An education is an achievement, not a gift. It can be neither inherited nor bequeathed. Fortunately there is only one way to get it. One must work for it and continue working to keep it.

Education means development, growth, evolution, discovering one's self. It is impossible for one to do until he knows. It is, however, infinitely more important to do than to know. It is possible for the athlete to develop physically by living naturally and constantly exercising. In order to continue being an athlete, however, he must not only continue to live naturally and temperately, but must also continue to exercise his body and keep not only it but his brain under control.

With the mind it is much the same. Once trained it also must be used, exercised, and, like the athlete's body, must be ready upon demand to rise to a supreme effort. Mediocre endeavor stifles progress. The constructive, creative mind must work in order to achieve.

The man is best educated who is most useful, the most capable of service. An engineer is one "competent to conceive, devise and organize the directing of the forces of nature to the use and convenience of man."*

The systematic, organized education of engineers in this country has now continued uninterruptedly for approximately a third of a century, almost exclusively in schools and colleges of university rank. The membership of this Society consists almost exclusively of men intimately connected with the work of educating young men who have the ambition to become engineers, and a very large part of the present members have first been students, and later teachers, of engineering during a large portion of this entire period.

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* Prof. D. C. Jackson, Proceedings American Institute of Electrical Engineers, 30th Annual Convention, Cooperstown New York, June, 1913.

From an academic and theoretical standpoint many features of such work have been discussed more than once during these years, all having directly or indirectly to do with the formulating of the curricula or courses of study best suited for the training of engineers. The number of graduates from the engineering departments of American universities and colleges has now become sufficiently large to justify analysis leading to conclusions that can not be misleading. Also, the number of engineering students and graduates in the United States has become less during the past few years, so that a bench mark, so to speak, or point of inflection on the curve has been passed.

No one can, with truth, deny that considerable success has crowned the efforts of engineering educators to date. However, political, economic and financial conditions have changed in recent years and are undergoing even greater and more rapid changes at the present time, and if the engineer is going to continue his useful and effective service to mankind he must not be oblivious to the changed conditions, but must carefully and seriously compare the present with the past in relation to the work of the engineer so as to most wisely plan for the future.

It is therefore not only worth while, but quite necessary, to now concern ourselves from an academic as well as a practical standpoint with the next or future period of engineering education.

During the life of engineering training as such there have been made a myriad of inventions having to do with steam, electricity and the transmission of intelligence, every one of which has rendered possible, and as a result demanded, the expansion of man's energy and opportunities. During the same period there have been enacted almost innumerable laws having for their purpose and avowed object the restriction and control of man's initiative effort and energy. Necessity has forced, and the prospects of reward have encouraged, economic transformations and readjustments so that the *rate* of living is greater today than ever before in the world's history. Business transactions are consummated, very large and important schemes are planned and many kinds of social intercourse are carried on even across the continent by the use of the modern telephone. The needs of the day require the most able, loyal and wise cooperation to meet the exigencies which arise. More is constantly expected of the individual, whether he be leader or follower, the race is swifter, and real laurels are denied to all but the especially strong.

The responsibility of caring for himself is always a necessary factor in man's evolution, but it is more necessary today than ever before. Isolation from the world to prepare for the world's work is now held to be an error. Man is equipped for a life of usefulness by qualities, not as a result of the mental possession of facts. The institution that best helps to develop the most desirable qualities and the best type of character, not the one that imparts the most information, will in future be known as the successful and superior college or university.

To fully and completely analyze the present, and especially the future, economic, financial, social and engineering problems, men must be trained to observe, think logically and constructively, and act decisively, just as the athletes are trained to have strong, active and efficient bodies.

Are the men who have been educated at the engineering schools of this country doing as much as might reasonably be expected of them in this broader field, remembering that capable and wise men are few and far between? Do university trained men of the engineering profession contribute a fair share of the leaders and wise men possessing alert yet sound judgment? The answer, it is to be regretted, must be in the negative. Rapid as has been the perfection and utilization of scientific and engineering devices, very few college trained technical men have risen to the demands of the occasion, to, in the most economic and satisfactory manner, plan for the community's largest interest. Leaders and organizers, often trained in the practical school of experience, have for the most part been in supreme command, while very often practically their entire staff of assistants have been engineers with a college diploma.

There are notable exceptions, and of course it is unreasonable to expect all young men who succeed in completing a college course to ultimately qualify for leading positions of administration and direction. Nevertheless, it seems patent that, considering their superior advantages and opportunities, technically trained men have fallen far short of what might very properly have been expected of them. What is of infinitely more importance, however, is, that if present indications are not misleading, there is every reason to believe that in the next two or three decades a decidedly less percentage of the total number of technical graduates will achieve positions of service calling for great administrative ability and superior leadership.

While supporting this view I will also hope to make some observations and suggestions that may be found more constructive than critical.

It is first necessary to clearly outline what to me seem the primary objects of either a four or five year undergraduate course in engineering. Having outlined the desired result, I shall indicate some changes in the present engineering courses, more in spirit than in detail, in presentation than in content, which may tend toward securing those results.

It is to be assumed that the young men entering college will be of an average age of eighteen years so that ordinarily they will complete the undergraduate course by the time they are twenty-two. Before entering college they are supposed to have graduated from or completed the equivalent of the work given in, the ordinary high school. They should be prepared to successfully undertake the courses in the freshman or first year of any one of the many American engineering schools. I should prefer that they enter with a modern language, because it is my experience that it is very much easier for a young man to obtain a grasp of a foreign language before entering the university than during the freshman or any other year in college, at a time when his main interests are devoted to the fundamental and applied courses in the engineering curricula.

I feel strongly that the main objects of an engineering or indeed any other course worth while in one of our universities are not so much to impart information as to train the mind, to teach underlying principles, to impress ideals of high standards, to insist on personal efficiency, to spur to superlative effort and to encourage broad leadership. Industry, accuracy and painstaking, serious work are obviously essentials. Clean living and wholesome companions are of more importance today than ever before, and yet while at most of our colleges and universities cigarettes, alcohol and automobiles are optional, a stranger on seeing the devotion of many of the students to them would surely suppose them all to be rigidly prescribed courses.

I am not unmindful of the lack of preparation and the limitations of the average college student about twenty years old. Very few have had any serious mental training and even fewer know how to study, which results in a general tendency toward imitation. The majority of engineering students have little or no ability to express their ideas in correct, clear and forceful language, either written or spoken. Students find many distractions from serious study. College activities are more than merely worth while. For three years the senior, or final, year of student days is very properly looked forward to as the time when not only the most important courses will be undertaken, but also when the heaviest responsibilities come in all student affairs, student government, college publications, athletics, social functions, and with engineering students the necessity of completing a thesis and usually the securing of a position after graduation.

The four years in college may profitably be compared to a life. In both one may get a superficial start on account of some real or apparent pull or influence, but in both, the one who really has it in him, independent of his family, friends or social position, will come out really successful. If a young man goes to college and there makes good in the right sense it certainly encourages the hope that he will do the same in the larger game of life. As a student he himself must do the work, but his teachers have a large responsibility, particularly to first prevent his losing his sense of proportion as between his university work and his student life, and second, to assist in his gaining a broad viewpoint and establish the proper relationship and continuity between his several university courses.

It is my firm conviction that throughout the entire four years every student in every course should get something of more importance than the content of the course itself, should have every subject presented in such a manner that its relationship to all other courses of instruction is made clear, be warned of the result of attempting to become a mediocre specialist in narrow fields of endeavor, and above all, be urged and inspired to strive, in college and out in the world, to obtain that broad foundation and viewpoint which is so necessary to leadership in the affairs of life.

There are two oriental maxims which translated are:—

> "It is the parent who has borne me; it is the teacher who makes me man."
>
> "Thy father and mother are like heaven and earth; thy teacher and thy lord are like sun and moon."

Here we are the crux of the problem.

"It is the teacher and not the subject or the equipment or buildings and apparatus that makes the enduring institution; but until teaching is unified to a much greater degree we shall fail to attain that degree of educational efficiency which will enable us to reach the limit of our ideal."*

What types of men are to be found on the staff of instruction in the engineering departments of American institutions? I have presumed to classify them into three separate groups:

I. The theoretical engineer who in reality is not an engineer at all. For the most part he teaches out of books and is neither to any great degree an original scientist nor an original thinker. His status in the academic world is reasonably well established but usually he is practically unknown in the broad field of real engineering and academic achievement. He faithfully and conscientiously does his work, although he has no conception of the continued consistent endeavor, at high speed, which is demanded of his colleagues not within the academic sphere. In universities he is the hewer of wood and the drawer of water.

II. The applied scientist who is an original thinker and an investigator, who has done—sometimes much, sometimes little—research work of considerable scientific and engineering importance. He is not necessarily what is generally called a good teacher, but is of a creative type, his work being known and appreciated in the scientific and engineering world.

III. The real engineer, who can design, create and interpret, and who has that broad concept of life which enables him to adapt and organize the forces of nature efficiently and effectively to the service of his fellows. He is a leader and administrator, has executive ability, and his work includes consideration of money expenditures, which is one of the basic features of engineering practice, but has little. if anything, to do with either pure or applied science. He lives in the world of extraordinary endeavor, has knowledge first hand of the details and economics of his profession, is capable of clearly distinguishing between engineering and financial difficulties, and fully appreciates the value of time.

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* Presidential address of Dean Gardner C. Anthony, Society for the Promotion of Engineering Education, Princeton, June, 1914. Dean Anthony does not come from California and therefore he will not be offended if I quote him after the oriental.

All real executives are of necessity good teachers. Unfortunately, for proper reasons perhaps, there are relatively fewer teachers of the third class in our engineering institutions than is desirable. There would not be as many as there are had not the administrative heads of many engineering schools begun some years ago to permit such men to do what is generally termed ''outside work.'' The wise and proper provision should be made, however, that the outside work should be beneficial to both the institution and the instructor.

It is not my purpose to suggest any material modification of the content of the present curricula of engineering courses, to advocate a five instead of a four year course, or to urge that an A.B. degree should be required for entrance to what would then be definitely a professional or graduate school of engineering. I believe in maintaining at least present standards of admission, but do not deem it wise to place in the path of all what would be for many an insurmountable obstacle to obtain that kind of an education best suited to many young American boys. I would, however, materially change many of the courses now given in all of the four years. If I had a son and it were impossible for him to acquire a trained, systematic and organized mind and achieve mental and judicial poise in any other manner, I would not object to his being taught mathematics practically exclusively for four years, not for the knowledge he might acquire or the subject, nor even for the mental discipline ordinarily supposed to result from a thorough mathematical study, but that he might in the end appreciate that mathematics may best be utilized as a method of logic, as a means to an end rather than as an end in itself, and to secure his using its processes, logically interspersed among conclusions, even when these of necessity must essentially be in the nature of compromises.

No single course or group of courses should be expounded without the most painstaking effort being made to bring out their applications and especially their limitations in the real issues of life. It is even more important to impress upon students the inter-relation of all courses in the curriculum, that no one subject should be held unduly important, but that the entire course of study as a whole becomes, as it were, a part of the students themselves. Then the graduates should be well on the way toward the ability to "direct the forces of nature to the use and convenience of man."

Those in responsible charge of the instruction in engineering in our American institutions can not but be impressed with the splendid development of agricultural education in recent years. Now our schools and colleges of agriculture are attracting a great many students. In the earlier years agricultural education was more scientific than practical, more academic and theoretical than instructional, especially as far as the undergraduate students were concerned.

Partly as a result of the earlier work in the various departments of agriculture in the state institutions of the country, but also because of a decided economic change in the relation of agriculture to other wealth production, we find the present extensive and sound development in agriculture not only in our universities, but in the country in general.

There is a certain parallel between engineering and agricultural instruction and engineering and agricultural development. Many of the members of this Society will probably, as students, remember most vividly the entire lack of mutual interest between engineering and agriculture. There is now, however, a very definite inter-relationship between the two, and in the years to come the work of many engineers will be required in the service of those in charge of extensive agricultural developments. The most constructive and effective work will result if our universities succeed in turning out engineering and agricultural graduates with the ability to conceive and direct all the forces that must work in harmony in order to accomplish the most desirable results for the benefit of the people of this country.

Instruction in agriculture undoubtedly is more directly in touch with the lives of the people than is the corresponding work in engineering. Individuals carry on the practical work of agriculture, while for the most part great organizations are required to accomplish important engineering feats, and it probably will be found that considerable modification will be necessary in agricultural instruction before it may be said to have become as standardized as that of engineering at the present day.

The recent introduction of practical courses in agriculture accompanied by the great increase in the number of agricultural students, indicates to my mind the necessity of critically examining our present courses of engineering instruction to the end that they may accomplish the most desirable results. Agricultural development in the immediate future demands a large number of college trained men, just as the engineering industries have been greatly benefitted by engineering graduates during the past twenty-five years. But the kind of a college trained engineer that is in most demand today is a much more able man than formerly. In life's endeavor the competition between college trained engineers is now much more keen than in the early days of engineering education.

I repeat that I am not advocating material or radical changes in the present curricula of engineering schools, nor do I wish to be understood as maintaining that a large percentage of our graduates can be made into leaders and men of large affairs. I do maintain, however, that a much too large proportion of engineering graduates, after being as many as ten years out of college, find themselves definitely and permanently diverted into narrow fields of endeavor, and to the end of their days will, in all probability, be working continuously in doing routine work which, while such may be engineering, will need an adjective ahead of the word "engineering" in order to indicate its extreme limitations.

It seems to have been necessary to bring into use these adjectives, that have been now largely introduced as a prefix to the word "engineering," even down into our four-year engineering courses in order to more definitely designate the kind of an engineer we are trying to develop. These adjectives are so numerous that I have no ambition to be known as the originator of a new one, but I am interested, however, in the development of a type of engineering graduate who is first of all a thinker and organizer and an administrator, but under and throughout it all a clear-headed engineer, not only in technical but in economic and financial matters.

Detailed, first-hand knowledge must be gained in the most modest, painstaking manner in the earlier years after leaving college before the technical graduate may become an engineer, but he should receive, and take from his alma mater lessons well learned in methods of study and mental processes, and in addition a full realization of the fact that to be of the greatest loyal service to his fellowman it is incumbent upon him to organize and administer not only with technical knowledge but also understanding fully the financial and economic relations of engineering work to mankind.

In trying to do this for our young men it would be a backward step to introduce additional and more specialized courses into our already much adjectived engineering curricula. It is necessary, however, for teachers of engineering to constantly impress upon students that the greatest opportunities for the majority of them, except the most gifted creative minds, are inseparably connected with the hardest concentrated work, and the most valuable service they can render others will require leadership, administrative ability, and a combination of character, technical skill and sound judgment.

DISCUSSION.

Professor W. J. Risley: It seems to me that Dean Cory's paper is on the line of engineering education. The remarks I want to make have some point with reference to Dr. Mann's address and some with reference to Dean Cory's paper.

The figures of Dr. Mann are apparently awful. They show 505 individual flunks. The number is increased by numerous additions of less than five per cent. of the total. We are also reminded that these 220 men completed the regulation, let us say 140 hours, plus the hours they flunked. Five hundred and five flunks at four hours per course give 2,020 out of 30,800 hours in the entire course, or seven per cent. It is an average flunk of two and three tenth courses per student. It seems that the physics people, the modern language people, the English, calculus and chemistry people must have done pretty much of a cleanup job, because of the fact that the technical engineers had to pass practically everybody after the others had completed their courses. The men we saved were evidently worth saving. The conclusions from the tests which were put under way will have to do with the future engineer. They are not reliable with respect to conclusions as to whether a man will succeed or not, or even whether he ought to study engineering when he comes to college. They are helpful however, if one uses good sense and does not follow the tests too slavishly. All of you engineers use good sense and so would not follow the tests too slavishly. There has but recently been undertaken a so-called scientific study of the college student. We advocated recently that all people should go to college, and now we seem to have come to the place where we must put the brakes on and decide which ones of these should be permitted to enter.

Dean A. A. Potter: The efficiency of a teacher of engineering is affected by the practical experience he accumulates while engaged in teaching. No matter how much practical experience one may have when he enters college work, he must keep in touch with the progress of his specialty. What does the teacher of engineering do during the three months of his vacation? What opportunities are afforded him for vacation work? I should like to see the Society add a committee for the purpose of investigating this matter of employment of engineering teachers during the summer vacation. Accordingly, I beg to move that the chair appoint a committee of three or five to look into this matter, and to include in its report to the Society the following:

1. Present status of summer employment.
2. Opportunities for such employment.
3. Fields recommended.

Dean C. L. Cory: I fear it is impossible for me to very effectively answer Dean Potter's questions. This is certainly a matter which we who are interested in engineering education have universally found a difficult problem. I am firmly convinced that it is impossible to make any general statement, as to what are the opportunities of the engineering instructor to obtain practical experience in engineering and continue his profession as a teacher without interruption.

Naturally, conditions vary greatly in different parts of the United States. I believe I know how very different the situation is on the Atlantic coast from that in the Middle West, and again, it is still different in the Rocky Mountain region and upon the Pacific coast.

There are, however, real problems of engineering of broad character that may be taken into our laboratories, but on the other hand, there are problems that can only be worked out in the field.

Many of the large manufacturing companies, as we know, have given opportunities for instructors in engineering to do summer work in their shops, laboratories and designing rooms. Many of the larger public utilities offer similar facilities for university instructors during the summer vacation. It has been found, I believe, that in the regulation of public utilities the Interstate Commerce Commission and the various state public utility and railroad commissions have found the assistance of the teachers of engineering in our American universities not only most valuable but quite effective.

I would not have what I have said in this discussion considered in any way as an answer to Dean Potter's question, but only in the nature of a suggestion.

INSTRUCTION IN ILLUMINATING ENGINEERING.

BY L. B. SPINNEY,

Professor of Physics, Iowa State College.

This paper is to be regarded as a contribution from the Education Committee of the Illuminating Engineering Society. Its object is to direct the attention of the members of the Society for the Promotion of Engineering Education to the importance of the subject discussed, briefly to mention the work which has been done in this field, and to point out the increasing need of more and better instruction in this branch of engineering work.

In presenting for your consideration, the subject of instruction in illuminating engineering, it will be safe to assume that the topic is already familiar to engineers, particularly those engaged in engineering education, and that each member of this organization is more or less fully advised of the efforts which have recently been made to arouse more general interest in illuminating engineering.

It has been pointed out that the new interest which is taken in scientific illumination and the agitation for more and better instruction in the science of illumination, both inside and outside the technical institutions, is not due to a sudden discovery of the need for better lighting, or the desirability of securing safer, more comfortable and more efficient illumination; but rather to the recent remarkable achievements of the lampmaker's art, which have made good lighting possible. The development of modern artificial illuminants, which, in efficiency, flexibility and adaptation surpass the fondest hopes, if not indeed the wildest dreams of the illuminating engineers of a few short years ago, has opened the field and created the demand for illumination based upon scientific principles.

In former times the means at hand for securing good illumination were wofully inadequate and it was very generally understood that the attainment of even approximately satisfactory results was possible only at extravagant cost. This condition was scarcely calculated to interest the public in the refinements of illumination. although without doubt it did serve to stimulate the specialist in his efforts to develop some more efficient form of illuminant.

With the advent of modern high efficiency sources, which have not only made good lighting possible. but have placed it quite within the reach of all. the situation has changed. and the demand for proper lighting has come to be as general as it is insistent. This widespread demand for better light led naturally to a more careful inquiry into the nature of good lighting with a view to determining its characteristic features, how it may be measured. how specified. and in what terms we may express its value. Out of these investigations has grown the science of illuminating engineering.

As already pointed out, this is a new field of interest and endeavor. The Illuminating Engineering Society, the first organization of its kind, was formed but ten years ago, while half that period covers the activities of the similar German and English institutions which received much of their inspiration from the successful work of the national organization of this country.

The Illuminating Engineering Society having as its principal objects the promotion of the science of illuminating engineering. the spread of knowledge of the underlying principles of good lighting. and the arousing of more general interest in scientific illumination. has done a great work. and has achieved well merited success and recognition.

It has investigated and compared modern illuminants and the methods of producing and distributing light; it has published exhaustive researches pertaining to the fundamental problems of artificial and daylight illumination; it has demonstrated the value of good lighting and the deleterious effects of improper and insufficient illumination.

It has compiled statistics showing the enormous numbers of school children of defective vision and has demonstrated that a large percentage of such cases are directly traceable to the improper illumination of the school room or the home in which the child's study work is done.

It has investigated the matter of accidents in factories and its relation to lighting conditions, and has shown that in those seasons and under those conditions in which the lighting is good, accidents are relatively few in number, and that most accidents occur during the darker seasons and under insufficient illumination.

It has published a primer entitled ''Light, its Use and Abuse'' which is intended to interest the layman and instruct him in the proper use of light. This pamphlet is widely distributed in this country and abroad.

Coöperating with the authorities of Johns Hopkins University, the Illuminating Engineering Society in 1910 arranged for a course of lectures in illuminating engineering at Baltimore. The lecturers were recognized authorities in such fields as the physical basis of light production, the psychology and physiology of vision, the manufacture of illuminating gas, electric distribution, exterior illumination, and the artificial and daylight illumination of interiors. These lectures have been published and have served as the basis of a number of courses in illuminating engineering in technical institutions.

Among the standing committees of the Illuminating Engineering Society is the Committee on Education, whose object, as its name would indicate, is the furtherance of the cause of instruction in the principles of scientific illumination. The activities of this committee have extended along several lines, among which may be mentioned the distribution of literature, the classification of text-books and other works on various phases of illumination and a systematic study of the courses in illuminating engineering offered in the leading technical and collegiate institutions of the country.

In the broader field the work of this committee is supplemented by that of the School Lighting Committee. Committee on Popular Lectures, Committee on Lighting Legislation, Exhibition Booth Committees and the Committee on Reciprocal Relations with other Societies.

It is hoped that the activities of these committees, and in particular those of the Committee on Education may receive special attention from those interested in engineering education since they are believed to embody the latest and most significant contributions to the cause of good lighting.

In the investigations of the committee on education last year communications were addressed to more than one hundred universities, colleges and technical institutions containing a brief statement of the work of the Illuminating Engineering Society directing attention to the importance of the subject of good lighting and requesting information concerning various phases of the courses offered in illumination and allied subjects.

The results of the investigation indicate that the subject of illumination is receiving considerable attention. Courses are offered which range all the way from brief mention of the subject in courses in physics and electrical engineering to extended and pretentious courses in illuminating engineering. The replies of many would indicate that the subject is worthy of careful consideration at the hands of those in charge of the curricula of technical institutions.

Among the activities of the committee on education this year is the investigation of conditions of instruction in good lighting given as a part of the regular work in high schools and schools of home economics of collegiate rank.

A letter from the chairman of the committee contains the following information:

Inquiries were sent to superintendents of schools in two hundred selected cities throughout the United States. Replies from forty schools have been received. "With few exceptions, replies do not indicate a very great interest in the work."

To about two hundred and fifty schools of home economics was sent a questionnaire accompanied by a letter containing the following statement:

"You have doubtless been following more or less closely, the rapidly developing movement to secure, on the part of the general public, a larger appreciation of the necessity for and the benefits to be derived from a more careful study of the means available for lighting our homes, public buildings, streets, etc. Of the deleterious effects of bad illumination much has been written in the scientific and technical press. Much time and energy has been given by various investigators, to the question of how these evils can best be remedied. with the result that at the present time certain fundamental principles as to satisfactory methods of securing good illumination are available for those who wish to use them.

"The Illuminating Engineering Society, through its various committees, has given much attention to the matter, and in furthering the cause of good lighting desires, so far as it is possible, to enlist the services of educators throughout the country. To this end the Committee on Education is attempting to ascertain the status of instruction in good lighting in the various schools and colleges, particularly in schools of domestic economy, through which those interested in improving conditions of home lighting are best reached.

"May we therefore ask you to assist us in making this canvass as complete as possible by answering the enclosed questions regarding instruction in good lighting in your department."

"To date replies have been received from fifty-four schools. It is very gratifying to report that the keenest interest in the work of the committee is shown by the directors of these schools. Almost without exception, they report that an attempt is being made to give suitable instruction; but that the work is being greatly hampered by a lack of non-technical information. When one considers the extent of the influence of these schools of home economics, the conclusion is obvious that here is a fruitful field for furthering the cause of good lighting."

These investigations of the Committee on Education serve to emphasize the fact that there is real and growing demand for more and better instruction in illuminating engineering. This demand presents a double aspect. There is need of a more general knowledge among the people of the value of good lighting, and the bad effects of improper illumination, and on the other hand there is a demand for those skilled in the application of the principles of illuminating engineering.

It seems natural to turn to our technical schools for help in meeting these demands. If the objection is raised by some that illuminating engineering is not a science, but rather an art, and therefore has no proper place in an institution whose work is scientific in nature, the answer is made that illuminating engineering has a sound scientific basis, and without such foundation illuminating engineering work is impossible.

"Illuminating engineering is both a science and an art. Science, according to Ruskin, is 'the knowledge of things, whether ideal or substantial,' and art is the 'modification of substantial things by our substantial power.' Science is knowledge, coördinated, classified, systematized. 'The object of science is knowledge: the objects of art are works. In art truth is a means to an end; in science it is only the end.' The science of illuminating engineering is the correlated knowledge of the varied phenomena of illumination; the art of illuminating engineering is the application of this classified knowledge to the design of lighting installations."*

To educate the public to the value of good lighting is a matter presenting no great difficulty. This will be accomplished when educators come to a realization of the importance of the subject.

The demand for trained engineers in this field can be met by the establishment of courses in illuminating engineering. This, too, will be done when technical institutions having facilities and equipment have become sufficiently interested. There is here a wide and useful field and the hope is expressed that ere long it will be recognized.

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* E. P. Hyde, *Trans. I. E. S.*, Vol. V, p. 540.

The Committee on Education can only direct attention to this subject. It has formulated courses in illuminating engineering, and is ready and willing to assist in shaping and organizing such work. It is believed that in its field of action, in promulgating the doctrine of more and better light, and in urging careful consideration of lighting conditions in the street, in public buildings, and in the home this committee is doing a work of importance and of lasting value.

Discussion.

Professor F. C. Caldwell: As one of the pioneers in this field, I am glad to have the opportunity to emphasize what Professor Spinney has said with regard to the importance of illuminating engineering education. The need for it in the case of engineering students other than those who are planning to make a specialty of electrical engineering is to be emphasized. The application for students in architecture is very obvious and yet in many cases they do not get adequate instruction along this line. Again, in the case of mechanical engineers, especially those who are going into industrial work, the question of lighting factories is one of great economic importance.

Professor W. S. Franklin: I would like to add a word in emphasizing a point Professor Spinney brought up and what Professor Caldwell said. I have also been much concerned in the work of the Illuminating Engineering Society, and I am sure our engineering teachers do not fully appreciate the importance of illuminating engineering, which has come so speedily into prominence. It is one of the most important branches of engineering instruction at the present time.

CLASS AND LABORATORY WORK IN ENGINEERING.

BY WILLIAM C. BAUER,

Professor of Electrical Engineering, Northwestern University.

The purpose of this paper is to direct attention to certain fundamental principles of general educational methods, which we as engineering teachers should more fully recognize in order to gain the fullest measure of success in our professional teaching.

We are often too much engrossed with the purely technical side of our subjects and we fail to pay attention to the best methods of presenting our technical matter. Recognizing the need of cultural training for our engineers, we are requiring among other subjects such subjects as psychology and logic. But, do we always give our students good concrete applications of these subjects when we present to them our fundamental technical principles?

I desire to emphasize and to discuss briefly the following:

1. That the fundamental aims of both the class and laboratory work are identical.
2. That very often we place too much emphasis on, "what are the phenomena," "what is the practice," and not enough upon the "why"—the rationale of the phenomena, or the "why" of the practice.
3. That in presenting our fundamental principles we do not always use the best methods of psychology and logic.
4. That in many cases there does not exist a sufficiently close affiliation between our class and laboratory courses; that we do not use the best sequence; that our work is not sufficiently truly progressive.

1. Fundamental Aims.

As Chaucer has expressed it, "Man hath sapiences three, Memory, Engine, and Intellect"; as Emerson has put it, "Every man is born with certain aptitudes."

Broadly speaking, there are three periods in the life of a human being—the period of birth, when he comes as a bundle of latent talents; the period for training these talents for service; and lastly, the period of service.

The college comes in contact with the individual during a very brief part of the second period. Its prime function is to assist in the training of human talents, in directing these talents to act.

The prime function of that human talent "Intellect" is "to reason, to perceive relationships, to constitutively build up," and the fundamental aim of both our class and laboratory work should be exactly the same, namely, to train the intellect to perform these functions, to develop in the individual those latent powers which are his by birth, to train him to put those talents into action. Every worthy human effort is the result of trained talents in action. It is our duty to train born engineers.

In giving an engineering education there are two things we must accomplish. We must impart engineering and scientific knowledge, and we must train the intellect to function properly.

What does "education" mean? The word comes from "educere" which means "to lead out, to call forth," to educate means therefore to call forth human talent, and "it implies not so much to *communicate knowledge,* as it does to *discipline the intellect.*"

There appears to be less danger in our engineering courses of falling short in the fulfillment of the duty "to communicate knowledge" than in the fulfillment of the duty, "to discipline the intellect." It is upon the latter that I wish to place particular emphasis.

Whether the student is in the class room studying phenomena by the use of symbols, verbal forms and mathematical expressions, or whether he is in the laboratory studying them in the concrete, we must ever remember that our fundamental aim is always the same, namely to train his talents to act, to make him reason, to start trains of thought. We should ever remember that machines in the concrete are but means to the end, external stimuli to set into action dormant undeveloped talent. Any class or laboratory period which has simply "communicated knowledge" and which has not resulted in producing a better thinker, which has not exercised the intellect, has in a large measure failed of its true function.

The true function which our laboratory courses should perform is to reinforce in the concrete the fundamental theories which underly engineering practice and to demonstrate the principles, the reasons for that practice. The true function is to make the student reason and to give him food for thought.

2. Too Much Emphasis on the "What" and Not Enough on the "Why."

Psychologists tell us that we learn only to the degree that we make mental adjustments. Just what that mental adjustment may be in any given instance is not always clear, but it may be safely assumed that mental adjustments are made and the intellect thereby strengthened by healthy exercise when the student constantly places himself in a questioning attitude. If he places himself in this attitude he will constantly ask himself, Why? Why? He will not accept uncontested, rule-of-thumb directions or dogmatic statements of facts, but he will place himself in that attitude which Professor Angier in a recent most excellent paper termed an "attitude of verification." It is the duty of the engineering teacher to encourage the student by every possible means to assume this attitude in his class and laboratory work. I cannot too strongly emphasize this point. I believe that we may test our ability as teachers by the degree of skill we attain in creating the attitude.

Although we do emphasize the "why" of practice, still I believe we should emphasize it more than we do. Too many of our laboratory studies resolve themselves into determining what is the water rate of an engine, or what is the efficiency of a motor or of a generator. Efficiency is an important factor, but for the student the all important point is, why is the engine efficient or, rather, why is it inefficient? It is far more important training for him to analyze the losses, to determine the various elements which produce the inefficiency, the relative value of each, and to study methods for reducing the losses.

It has been stated that one of the functions of education is to secure "intelligent adaptability," "that we may test our education by the readiness with which we adjust ourselves to new conditions." To adjust ourselves we must possess the power of analysis and of discrimination. In a recent article it was stated that "our laboratories must be ample to demonstrate modern methods and practice." This statement omits the main point. The laboratories must demonstrate the principles of modern practice, the relation between modern and past practice, and the reasons for modern practice. Such laboratory methods lead naturally to considering the possible direction in which future practice may tend. It may be safely assumed that the student who has been trained in the "why" of the practice will not experience so much difficulty in applying fundamental principles in practice, and in adjusting himself to new practice, as the student who has merely been demonstrating modern practice.

It is perhaps in our laboratory work more than in the class room that the danger of over-emphasizing the "what" exists. We often yield too far to the cry for so-called practical courses in these days when much more elaborate equipment may be easily obtained. There is little danger at present of making the courses too theoretical.

Psychology teaches us "not to dwell too long on the concrete.—we must acquire the capacity of passing from object to symbol." Unless we heed this teaching we shall fall into the errors of Bacon's philosophy which fell short in that it supposed "no need of original speculation on the part of the investigatior," or we shall fall into the weaknesses of extreme empiricism, such as that of J. S. Mills, which "largely ignored the constitutive work of the mind and regarded knowledge as a merely passive reception of sensuous impressions." To give a well-rounded "discipline to the intellect" the student also needs the wholesome philosophy emphasized by Whewell, which "realizes the function of theorizing in inductive research." It should be our constant endeavor to dovetail our practice in with our theory. Placing emphasis upon the why, gives ample wholesome food for mental speculation and arouses trains of thought and trains that human talent, intellect.

3. Better Psychology and Logic in Our Methods.

Remembering that the prime function of the intellect is to reason, to perceive relationships, it becomes our duty to present our technical matter in such a manner that the intellect is made to reason and to perceive relationships.

What are the logical processes of reasoning? They are: Reasoning by analogical inference, by inductive inference, and by deductive inference.

Analogical methods are very valuable in suggestion. By analogy very valuable hypotheses and theories are often suggested, but in using this method great care must be exercised lest one is led to superficial and ofttimes to erroneous results. Inductive and deductive methods when properly applied always give correct results.

Engineering is sometimes defined as an applied science. This might be interpreted to mean that it resolves itself largely into a deductive science, but it is more, it is also an inductive science. It is true that many practicing engineers are largely concerned with the deductive application of general scientific principles to individual or specific cases. But as Professor Angier stated it, "we should invariably try to connect a general principle with its practical applications, and conversely to link the individual applications to their appropriate general principles." Our leading engineers are not merely deductive practitioners, they are inductive and deductive leaders.

Poor results and actual harm are often caused by the failure to employ strong inductive and deductive methods of reasoning in presenting fundamental principles. For instance, how frequently we see the statement, "Ohm's law does not apply to alternating current circuits." This statement is usually made when the study of alternating current theory is begun and then the author proceeds to develop the law which does apply to an alternating current circuit. It is true, Ohm's law in the ordinary form in which it is stated does not apply, but neither does the law of gravity, but Ohm's law bears a vital and close relation to the more general law which applies to any circuit, while the law of gravity does not. It is not incorrect to make such a statement, but harm comes from the suggestion that there is one law for a continuous current and another law for an alternating current circuit.

There is but one fundamental general law which includes all special cases. It may be expressed by the equation

$$I = \frac{E}{\sqrt{R^2 + X^2}},$$

in which I is the current, E the impressed pressure, R the resistance and X the reactance, either inductive or capacity reactance or both. Now it can be very easily shown that under the special conditions of a continuous current circuit, X becomes zero, therefore, the fundamental equation resolves itself under these special conditions into $I = (E/R)$, which is Ohm's law as ordinarily stated. Treating the law in this manner leaves absolutely no doubt in the student's mind that there is but one general fundamental law which covers all cases. The relation between the ordinary expression for Ohm's law and the general law is made clear and that function of the intellect "to perceive relationships" is exercised. The relation between general cases and special cases is forcibly illustrated.

Let us consider another similar illustration. That factor of an electric circuit known as the "conductance" leads to a great deal of confusion. Why? Because from the non-psychological and non-logical methods of treating it, the student is led to infer that conductance in a continuous current circuit is not the same as conductance in an alternating current circuit. If we derive the general equation for conductance which is applicable in all cases, then the student sees at once, that from a physical standpoint, conductance always means the same thing, but that its mathematical value may be different under different conditions.

It is only effort oft repeated which brings its reward and grows into a habit. We should put forth every effort to heed the advice of Professor Angier, and create in the student the habit of passing from a general principle to its practical applications, and also of proceeding from individual or special cases to the general principle. Such teaching not only communicates knowledge but it also trains and disciplines the intellect. We must improve in our methods of presenting general and special cases and the relations which they bear to one another. We establish too many separate theories for different machines investigated. I shall discuss this matter more fully later.

Invariably interlocking our general fundamental principles with our special engineering practice and studying the relation which special practice bears to general principles, will meet the complaint so often made that some of our courses are too theoretical or that some are too practical. What we want to develop is preëminently practical theory courses, not theoretical theory courses nor practical practice courses.

4. Closer Affiliation, Sequence, and Progressiveness Needed.

Class and laboratory work are often arranged in parallel courses. One instructor maps out his class course and another instructor maps out a parallel concrete laboratory course. These courses are often arranged with very little or no conference between the two instructors and like parallels the courses do not meet. Such a procedure I believe to be fundamentally wrong. Every effort should constantly be made, as stated by Professor Angier, in the quotation previously made which I shall repeat, "to connect a general principle with its practical applications, and conversely, to link the individual applications to their appropriate general principles." To form this habit requires that the two courses be thoroughly dovetailed together. This matter should receive our most careful consideration. Our most successful, our leading engineers, our makers of practice, so thoroughly typify this close interlinkage between theory and practice, that we should take them as examples.

As to the sequence of the two courses, I believe that in the majority of cases the best training in our undergraduate courses may be had by taking up theory first, at least to such an extent as to make the laboratory exercises intelligent studies rather than to make them perfunctory following of directions and making observations.

In the main our laboratory work should reinforce in a concrete way the fundamental principles and should test and verify our theories and our predictions.

What is it that very strongly characterizes our most successful engineers, the establishers of predecent? Is it not their wonderful capacity for visualizing fundamental principles, their power to see the finished structure in all its harmonious beauty with their mind's eye, their ability to prophesy or to predict by means of unshakable scientific principles and by means of rational mathematical processes, just what will happen under a given set of conditions? The old hit and miss, or cut and try, processes in engineering are out of date, expensive and inefficient, and they should not be resorted to unless the phenomena are so new that reliable theories for guidance have not yet been developed. It is the reliability of the engineer's plans, his predictions, that makes him successful.

The laboratory then is the place where the student is to develop confidence in his mathematical and theoretical predictions. The laboratory as an external stimulus should materialize his theories and fundamental principles. The student should make the concrete test or verify his prophecies. But the function of the laboratory must not end here. Each laboratory investigation should advance him a little farther on his spiral of progress and should widen his vision. Each study should start new trains of thought and bring new reward by establishing a foundation for further theory. Each study should supply its own concrete threads of evidence to be skillfully woven together into new relationships. Each study should strengthen the "constitutive work of the mind."

We should endeavor then to outline the work so that it is truly progressive. Not only must we make each laboratory study a beautiful marble building block in itself, but we must endeavor so to carve each block that it fits in its proper relative position in a harmonious whole.

Too often we look upon each laboratory study as an individual instance, all sufficient unto itself and we lose sight of the relation it bears to the whole. Too often we forget our fundamental structure and we study each machine as an individual. Professor Karapetoff has covered this point so well in the introductory remarks in one of his books, that I cannot do better than to quote him. "The advanced student must be taught to treat every electrical machine as a particular combination of electric and magnetic circuits, and to base its performance upon the fundamental theoretical relations, rather than upon a separate 'theory' established for each machine, as is so often done." In other words, each laboratory study should progressively confirm the all important truth that electrical machines are but special combinations of electric and magnetic circuits, and that when these two are properly adjusted any specific type of machine may be realized.

We must endeavor to create in the student the habit of focusing upon a new problem presented for solution all of his collective experience and theory, not merely some individual experience. When laboratory and class work are truly progressive, then each laboratory and class exercise in turn becomes a part of a well-woven fabric, the course. The sequence becomes natural.

It is believed that if we can realize the above ideals, then we shall have a truly philosophical method. If we study phenomena and machines in such a manner as to bring out the fundamental relations which they bear to one another and to the more general fundamental truths, then we shall fulfill the two functions of education,—to communicate knowledge, and also to discipline the intellect.

Discussion.

Professor A. H. Ford: I do not claim that I have solved the question of laboratory instruction, but there are some things which we are doing which I think have gone a considerable way in that direction. For example, we make no distinction between a laboratory course and a text course. If we have a course which requires laboratory instruction, it is taught as one course, and one man gives the instruction. By that method, there is no difficulty about coördinating the laboratory instruction and the text instruction. One man is responsible for both, so they can not get very far apart, unless that man deliberately removes the laboratory instruction from the class instruction. Frequently, in my own work, I will skip a laboratory problem, and devote the time to a lecture, or another time, to the text; or if it becomes convenient, I work *vice versa*, and take in extra laboratory periods, providing the program allows the extra time required.

Professor V. L. Hollister: We have found in the last two or three years a correlation between the laboratory exercises and class room discussions that is working out very nicely. I should like at this time to illustrate the fundamental scheme on which we have built this correlation. It is based primarily on the idea that the laboratory should classify the knowledge that is gained in the class room. You take studies like, for instance, "the predetermination of the efficiency and regulation of an alternator from the short circuit and open circuit characteristics." In this test vector diagrams and certain theoretical considerations are used to predict the performance of the machine. The experience gained in doing the test is very desirable, but as an isolated, unchecked piece of work the impressions left with the student lack connection and relation. Class-room discussions are needed to show wherein the calculations are accurate and where there are make-shift approximations. We have combined this test with the class-room discussion and also with further check tests upon the same machine in the laboratory. Reports upon the combined tests showing the theoretically determined results, the actual figures obtained from direct measurement, and a more or less complete written report are prepared by each student. That is, we have tended to group similar and related tests on particular machines so that results may be compared with their inter-relations studied. Combined reports on the complete study are received, and then we attempt to study the problem in class and, to some extent, in special conferences. It is the aim of the instructor to bring out the points that are valuable in connection with the particular test and at the same time give the student that perspective which might be gained from duplication of the same work on a number of different machines. This method of turning laboratory tests into more complete studies has worked out very well, I must say, much better than where the same experiments have been performed on the same machines and under the same instructions but without the inter-relation. I recommend the method as a means of making laboratory work more vital.

Dean C. L. Cory: One paragraph in the paper just read impressed me very strongly; as it is quite short I take the liberty of reading it to you:

"As to the questions of the two courses, I believe that in the majority of cases the best training in our own graduate course may be had by taking up theory first, at least to such an extent as to make the laboratory exercises intelligent studies rather than to make them a perfunctory following of directions and making observations."

It is the last part of the paragraph to which I wish to refer. I am inclined to think, in some instances, at least, that our engineering laboratories are so completely equipped, and arranged so conveniently for the use of the student, that about all he has to do is to close a few switches, or make a few attachments of the instruments to the machines to be tested, make a few observations of such instruments, and that is the end of it. Naturally, the student thinks he has performed something worth while, but of course he hasn't.

Personally, I would feel that this method of teaching engineering in the laboratory should be in every respect compared to the teaching of engineering mechanics by the memorizing of mathematical formulae.

In neither case is the student called upon to reason, or think out the problem.

I have also observed that many students of engineering seem to feel that the laboratory work they do renders quite unnecessary any use by them of the library. It has been very forcibly brought to our attention this morning that we should use the laboratory to the same end that we use our text and reference books. It is, of course, necessary to train the mind, and this cannot be done by merely routine work.

I have also observed that after graduation many young engineering graduates are quite content as long as they are engaged in construction work, but lose all interest, seemingly, after the construction period is ended, and the routine of operation begins.

I think this is as it should be in some respects, as our men should have the constructive instinct and not be satisfied very long with merely routine operation. Nevertheless, continuous, reliable service is quite as much dependent upon eternal vigilance in operation as upon equally important details in the construction of the original plant.

Finally, I beg to say that I am well aware that with the limited equipment and facilities in many engineering institutions, it is well nigh impossible to handle a large number of students in the laboratory and yet give them work which will at all times tend to develop their reasoning power and the ability to think. Nevertheless, experience most clearly indicates that in any real engineering problem, by far the most important factors are many times connected with the preparation for the work rather than in making certain observations after the experiment is begun.

Professor E. W. Kellogg: A working plan tried in a good many places in electrical engineering work has not been mentioned, though I think it is a matter of general knowledge—at least a good many people know of it. This is the idea of having what might be called a preliminary report, making the students write up in advance of the performance what they intend to do and what results they expect. I have used this plan in electrical courses at Missouri during the past year and am very well pleased with the results.

There are one or two little "kinks" in some of the work done there which might be of interest. One is for illustrating the action of alternators in parallel. I have found it interesting to the students and instructive to arrange two machines of the same number of poles. with their shafts practically on a line. running at the same speed. On the end of one shaft a disk is placed with a narrow slot in it. and on the end of the other shaft a disk with a white mark; and in that way we may observe the relative armature positions while the machines are running. I have found that a very satisfactory way of demonstrating the mechanical relations incident to paralleling alternators.

Another little scheme which has not been completed but on which we are now working. is an induction motor in which a rotating field can be produced, either by supplying direct current to the stator and rotating that mechanically, or by supplying stator windings with the alternating current. We expect to be able to bring home the idea of a revolving field and some of its consequences in that fashion more effectively than we can by means of standard methods.

Professor F. C. Caldwell: One point needs to be borne in mind in connection with the question of the coördination of laboratory and classroom work. and that is. the increasing difficulty in doing this satisfactorily with the growing size of the classes. With small classes the laboratory work can be kept along with the class work with comparative ease; but as the size of the classes increases, the difficulty of maintaining exact parallelism becomes greater, unless unusually liberal appropriations are available. We all agree that the closer the laboratory and classroom work are brought together, the better the results will be.

There is one other element that can perhaps be considered as something of a compensation where the laboratory work is behind the class work, and that is the effect of the review obtained. A man after doing the work in the classroom may partially forget it; then he comes to it again in the laboratory and he may get more reinforcement of the idea than if he had done it at the same time that he first met the subject in the classroom.

I have been pleased to note the increasing use of laboratory manuals, in which the student is required to study up the experiment for himself in other text-books. A laboratory manual in which the student is given complete instruction, so that all he has to do is to follow the directions given, loses much of the educational value of the work.

The matter of making connections and other preparations for the experiments has been discussed. Our policy has always been to have the student make just as many of his connections as possible, and at the same time to have it physically easy for him to do so.

THE ANNUAL COMPETITION CONDUCTED BY THE ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

BY J. H. LEETE.

Dean, School of Applied Science, Carnegie Institute of Technology.

For several years the New York Society of Beaux-Arts Architects has maintained a competition in architectural design which has been part of the program of work of about a dozen schools of architecture, among them being the Massachusetts Institute of Technology, the University of Pennsylvania, Columbia University and the Carnegie Institute of Technology. This competition covers twenty-five problems annually for the solution of which a varying amount of time is allowed, some of them being sketch problems to be completed within twenty-four hours. The solutions are sent to the New York offices of the Society where they are judged by the Standing Committee on Education. In some of the architectural schools a certain number of credits obtained in this way are required for graduation.

The possibility of establishing a similar competition in engineering problems was presented to the Engineers' Society of Western Pennsylvania in the spring of 1912 and as a result a committee consisting of five members prominent in the engineering work of the district was appointed to study the question in detail. This committee spent over a year in the investigation and discussion of many different plans, in the course of which the opinions of both faculty and students of schools regularly taking part in the architectural competition were consulted. It was finally decided to recommend to the Society the adoption of an engineering competition to be limited at the outset to the technical schools and colleges in the neighborhood of Pittsburgh. Some of the advantages which, it seemed to the committee, might reasonably be expected to be derived from a competition of this kind are as follows:

1. The setting of a problem by engineers engaged in the practice of a profession rather than by the faculty man would give to the student what he would regard as an opportunity for more intimate touch with his future profession. The attitude of mind thus induced would bring new interest to the studies of the course.

2. The incorporation in the scheme of instruction of a problem, apart from text book instruction, a problem complete in its way and stated as it occurs in actual practice, would afford an opportunity for the application to a single problem of many principles of instruction which are of necessity more or less disconnected in the usual schedule of studies. This assembling of the instruction of many teachers would be helpful in coordinating courses in the student's own mind. It should also give him a better appreciation of the close relation between the theoretical studies of his course and the problems of practice he is expecting to meet later.

3. The judgment of the problem by outside practicing engineers would appeal to the student and would result to a certain extent in the transformation of the instructor from the position of task-master to that of coach.

4. The opportunity afforded by this competition to get into closer touch with the practicing engineer and modern conditions of practice would be helpful in many ways to both instructor and student. It is very easy for instruction to get into a rut.

5. The determination of the character of the design and the material to be used in the building of the machine or structure from the considerations of safety, of the life demanded, and the cost of construction would introduce a factor difficult to accomplish by the usual methods of instruction.

In view of these advantages the Society unanimously adopted the recommendation of the committee and appointed a standing educational committee of five members for the purpose of working out the details of the plan.

The plan of the competition eventually adopted by the committee on education, while retaining some of the features of the architectural competition of the Beaux-Arts Architects, differs in some respects because of the different conditions existing in engineering schools. Briefly, the plan provides for the setting of a single problem in each of the principal fields of engineering practice, the problems for a given year being placed in the hands of the student at the close of the preceding school year. These problems are set in the terms of actual practice and involve the adaptation of the design to the life demanded and the cost of the structure. The solutions of the problems are due in May of the following year at which time they are viewed and judged by a standing committee of prominent engineers who are members of the Society. The points considered in making the award differ somewhat in the thought placed upon the different factors, but in the main the total of 10 points is distributed as follows: engineering judgment, 3 points, method of solution, 3 points, accuracy of work, 3 points, neatness of work, 1 point. No money prize is offered but certificates of first, second and third award and of honorable mention are given in each of the fields in which problems are set.

The purpose of the competition is primarily to promote engineering education, the competitive feature being regarded throughout as of secondary importance. The regulations governing the competition have accordingly emphasized the educational factor throughout. Every effort has been made so to arrange conditions as to make possible the closest coordination of the problems with the regular courses of instruction. For this reason it was thought advisable to allow practically a full year for the problems, thus permitting their introduction either into the regular work of the first or second semester or as a thesis subject as may be desired. The greatest freedom also is allowed in the method of conducting the competition, each school being responsible for its own students, the only requirement being that "the solutions shall represent strictly the work of the individual contestants without other assistance than directions concerning printed data and such general discussion as shall be consistent with honorable competition." As additional means of adapting the problem to existing courses of study the competition has been thrown open to students of either the junior or senior classes, as may best suit the convenience of the institutions involved. Only such solutions, however, are considered as bear the personal approval of the head of the department in which it originates.

Competitions were conducted under these plans in 1913–14 and 1914–15, a total of 331 solutions having been submitted. As stated earlier in this paper, it was originally intended to confine the competition to colleges and technical schools in the neighborhood of Pittsburgh but upon request there were admitted certain institutions at considerable distance, as for example the Georgia School of Technology, the University of Maine, Tufts College and Cooper Union. For the coming year it has been decided to throw open the competition to all the engineering schools in the country and with this in view announcements and specimen problems have been sent to the deans of many institutions. This extension was made as the result of the very favorable opinions expressed by the heads of departments in many of the schools in which the competition was held during the past two years. Responses to this invitation have indicated a considerable increase in the number of institutions to be represented in the competition for the coming year.

The purpose of this paper is to call the attention of members of the Society to the opportunities offered by this competition. From my personal observations of the results of the competitions of the last two years as conducted in the Carnegie Institute of Technology, I am convinced that the plan has accomplished even more than had been expected, and that it provides a most valuable adjunct to the usual courses of instruction of the engineering school. The problems have aroused real enthusiasm on the part of the student and as a result an amount of work has been accomplished in the fields covered by the problems which could not have been approached by any of the usual methods. The dean of one of the engineering schools which has taken part in both competitions, informs me that the competition has resulted in the somewhat novel condition of an instructor being fairly hounded for information. It has led many students to take voluntary trips of inspection for the purpose of seeing at first hand the kind of machine or structure called for in the problem. In our own school a large number of the competitors voluntarily devoted their Easter recess to work on this problem and indeed it has proved a real competitor with athletics and other student activities. I am convinced that the plan is worth the serious consideration of the faculties of all engineering schools.

Discussion.

Dean G. C. Anthony: If you can establish a relation between the student and the teacher such as exists between the football and baseball teams and their coaches, I think you will make a great advance in teaching. I want to bear testimony to the fact that this scheme of which Dean Leete has spoken will do that sort of thing. I have found that it is a good substitute for the thesis, and in many respects will do that which the thesis will not. As he has stated, it is not a problem assigned by the college; it is assigned by practicing engineers. It is a live problem and I know from practical experience with students that they regard it in exactly that light. They look upon it as a thing which may actually be put into operation. Indeed the form of one of the competition problems was so stated that they believed in the probable construction of a machine of the accepted design.

Two years ago when I heard of this competition I was in the vicinity of Pittsburgh and went to headquarters in order to examine it, not being favorably inclined towards the proposed method of doing the work. After I had talked with the committee I concluded that it was a thing worth trying out and I brought it back to my institution. The method adopted by the students in carrying on the work was most gratifying. As Dean Leete has quoted in another instance, I was fairly hounded by the student body. I told them that my relation to them would be that of consulting engineer. I would give them all the information I was possessed of, on being asked for it, but it was their work and I should not direct it. They came to me for considerable information and I gave much advice, considerable of which they did not take, and concerning some of which I believe it was to their credit. They went to three different cities and I was asked to accompany them. The investigation which they made in one manufacturing plant at which I was present was interesting. After thorough examination of the machine they interviewed the manufacturer and the workmen concerning the adaptability of that particular machine to the work, and then drew conclusions as to what they must do to meet the requirements of their specifications.

Another phase of the problem which interested me very much was the competition in the college itself. One of the subjects was the designing of a bridge, and as the problems were brought into my office one group of students interviewed me and wanted to know if I had seen Blank's design. They said that the estimates he had made and was going to submit were very low, and they knew, positively, he had cut the material in the bridge below what they considered proper but the man who submitted that design won an honorable mention which showed that he was not unreasonable in his estimate. I have never seen so much activity toward the close of the course as I saw in that competition, because in many cases men have worked all night on it. On inquiring for a certain man one morning the other students said, "He did not leave here until seven o'clock this morning." Provision had been made for lighting the buildings which were not usually lighted at night.

We entered into the competition a second time during the past year, and we are still more enthusiastic about it. We are going into it for a third time, regarding it as one of our courses now. I am sure that if any of you gentlemen who have not tried it will do so for one year, you will agree that it is one of the best courses which can be given to advanced engineering students.

Dean C. R. Richards: One element of danger in intercollegiate competition, which I think ought to be considered in connection with this, is the following: In the good old days, when intercollegiate athletics first came into prominence, the desire on the part of the students and the faculty to win led to the vicious practices in athletics with which we are all familiar. When intercollegiate debating first came into prominence, the same sort of thing was resorted to as in athletics. I know of a case where the coach did the work for the debaters, and where the results were not results of students' efforts, but to a large extent the fruit of the coach's work.

There has been for a number of years an intercollegiate contest among students of architecture. I am told that certain schools do not play the game fairly; that in order to win, the students do nothing but work on the competition for a period of three or four months. They drop all their other work and put the time in on the problems assigned. I should be quite fearful that unless we lay down rules, not as elaborate as those of the intercollegiate conferences, perhaps, in connection with these competitions, we may get into the same sort of difficulty.

Dean J. H. Leete: I wish to reply to that one feature. There is only one competition a year, and with a whole year allowed for work in the problems I hardly think that the competition has unduly cut into the work of other departments. With regard to the fairness and honorableness of the competition, the Society accepts no problem which has not the approval of the head of the department; and, therefore, there can be no suspicion of unfairness without impeaching the teacher.

Dean Richards: I merely wanted to call Dean Leete's attention to the fact that athletes are frequently certified to by the authorities at their institutions, when they have no right to compete.

Professor G. R. Chatburn: I simply wish to ask if Dean

Leete had any difficulty in getting the students started in the year, or did they allow the thing to drift along to the end of the year and then make up for the drifting by doing extra work at that time?

Dean Leete: In the first competition some of the students did start late but that was a matter entirely under our control. We simply withdrew two or three students from the competition because they did not show satisfactory progress in the work. This year we required them to keep up to a time schedule laid out by the department and we had no such difficulty.

Professor J. C. Shutt: I think there is enough in this work to make it worth while, even if competition should be eliminated entirely. I am sure I should like to have problems coming from practicing engineers presented to our students as routine work independent of competition. It does not require competition to get students interested in such work. I shall try to have this available for my students, and I shall hope that we may enter the competition as Dean Leete has suggested.

Dean Leete: Just one word. In this competition there is no financial reward, Dean Richards, while with the architectural competition of which you spoke there is a direct reward in the shape of the Paris prize. The fact that there are no money prizes possibly removes some of the undesirable features and places the competition on a professional plane. At any rate, the results achieved in the way of securing good hard work from the students are so satisfactory that we are willing to risk the question of possible unfairness on the part of the faculties directing the competitions, or at least to defer until such unfairness becomes a fact.

ENGINEERING THERMODYNAMICS AT AMERICAN COLLEGES.

BY A. A. POTTER,

Professor of Steam and Gas Engineering and Dean of Engineering Division, Kansas State Agricultural College.

With the rapid advance of the engineering profession and the multiplicity of the desirable subjects in the various courses of study, the subject matter and the time to be devoted to the various phases of any given course are becoming matters of increasing importance. Every subject must be carefully considered as to the place it is to occupy in the course of study, whether required or elective, the time in the course each subject is to be given, ground to be covered, and the relation between class room and laboratory instruction.

Subjects included under engineering thermodynamics.

In this paper under the title "engineering thermodynamics" will be included not only the courses in pure thermodynamics, but also the various applications of thermodynamics to steam engineering, gas engineering, refrigeration, etc.

The majority of engineering colleges, besides a course in pure thermodynamics, offer also separate courses in steam engines, steam boilers, internal combustion engines, and power plants. Some institutions require or offer as electives, special courses in steam turbines, mechanical refrigeration, compressed air machinery, locomotive engineering, heating and ventilation.

TIME DEVOTED.

It might prove profitable to make a study of the amount of time actually devoted to engineering thermodynamics and its application in our colleges. The figures in the table were calculated from the latest catalogs of the sixty-eight representative engineering colleges. The results were submitted in each case, for correction, to the professor of mechanical engineering at each institution. Out of sixty-eight institutions only eight professors neglected to correct the values for the institution in question.

A survey of the figures in the table reveals several points of interest. In the mechanical engineering course the time devoted varies from 6 per cent. at the University of Florida to 20.8 per cent. at the University of Nebraska. The average time allowed for engineering thermodynamics and its applications is about 12 per cent. of the total points or credits required for graduation. Several of the leading institutions including Brooklyn Polytechnic Institute, Case School of Applied Science, Cornell University, Lehigh, Leland Stanford, and several of the Land Grant Colleges exceed the average figures. The majority of the institutions devote in the mechanical engineering course nine to fifteen per cent. of the total points required for graduation.

In the electrical engineering course the figures vary from about 2 per cent. at The Ohio State University, University of Missouri, University of Pittsburgh, and the Case School to more than 12 per cent. at Cornell University, Michigan Agricultural College, and Tulane University. The average time is about 6.5 per cent.

The average value of 12 per cent. should be sufficient to cover engineering thermodynamics and its applications quite thoroughly for mechanical engineering students. It is the writer's opinion that the required time should be increased to about 8 per cent. in the electrical engineering course. The average graduate from an electrical engineering course is very nearly as much concerned with prime movers as is the mechanical engineering graduate, the cost and reliability of a steam-electric or gas-electric power plant being determined mainly by the prime mover.

Such subjects as heating and ventilation and compressed air machinery can well be eliminated from the electrical engineering curriculum. Also mechanical engineering students should devote more time to power plant design.

In the civil engineering course the values in the table vary from 1.1 to 6.4 per cent. The average of 3 per cent. should be sufficient to impart to the civil engineering student a general knowledge of the fundamentals.

ARRANGEMENT OF SUBJECTS IN THERMODYNAMICS AND ITS APPLICATIONS.

Some institutions give courses in steam engines, boilers, and similar thermodynamic applications in the freshman year, other colleges begin descriptive courses in the sophomore year, and still others in the junior year. Some institutions follow the course in physics by a course in pure thermodynamics and take up the descriptive and applied subjects after the student has had a course in pure thermodynamics. Several institutions give no descriptive courses as such relying upon the fact that the student interested in the course will find out for himself the construction and working of various prime movers and auxiliaries.

For best results a rigid course in pure thermodynamics should be preceded by a descriptive course of prime movers and auxiliaries. Such a course should be offered after the student has had a large part of the course in physics, probably during the second half of the sophomore year or during the first half of the junior year.

The average number of points or credit hours required for graduation in engineering courses are 145 for colleges having two semesters per year. This is equivalent to 218 points for institutions retaining the three-term academic year. A point or credit unit means in the majority of institutions one hour lecture or recitation per week or three hours of laboratory, shop or drafting room practice.

I had to write quite a few letters to determine this. I find that in the majority of cases students are required to take three hours of laboratory practice for every hour of classroom work. It occurs to me that the Committee on Statistics might do well to find out what is the best practice regarding the amount of laboratory work required in proportion to classroom work; also the amount of time required to be spent outside of the laboratory in the preparation of this work.

Basing the requirements for graduation upon 145 credit units and taking the average time devoted to engineering thermodynamics and its applications as 12 per cent. for mechanical, 8 per cent. for electrical, and 3 per cent. for civil engineering students, the following courses of study are suggested.

1. *Junior Year—First Semester.*—Prime movers. Four recitations and three hours laboratory per week. (5 credit units.) Required of all mechanical and electrical engineering students.

This course should include a study of steam boilers, solid, liquid, and gaseous fuels, combustion, valve gears, and details of steam engines, steam turbines and internal combustion engines. Separate text-books should be used for steam boilers, valve gears, and internal combustion engines. Several good text-books are available for boilers and steam engines. Unfortunately, there are no short descriptive text-books on steam turbines which can be followed by a student without the knowledge of thermodynamics. Considerable difficulty will also be experienced in finding a suitable text-book on internal combustion engines. However, as Professor Spangler once stated, "a poor text-book is a good deal better than a good lecture."

The laboratory course in prime movers should be carefully coördinated with the class-room instruction. The laboratory exercises should include: standardization of power plant instruments, analysis of fuels and lubricating oils, a study of the several valve diagrams as applied to steam engines, indicator practice, valve setting practice on steam and gas engines, brake and economy tests on steam and internal combustion engines. Several hours of boiler room and engine room operating practice may be desirable, but such work must be carefully planned in order to be of technical and teaching value to the student.

2. *Junior Year—Second Semester.*—Pure thermodynamics.

Four recitations and three hours of laboratory practice per week. (5 credit units.) Required of all mechanical and electrical engineering students.

This course should include: The fundamental principles showing the relation between heat energy and mechanical energy, properties of gases and the analysis of heat engine cycles as well as reversed cycles using gas, properties of vapors, and the analysis of heat engines and reversed cycles using vapors. In the study of cycles both the heat engine and reversed cycle should be taken up together, otherwise the student sees no connection between thermodynamics as applied to the heat engine and to the refrigerating machine. The problem attitude can be well developed in a course on pure thermodynamics, provided the instructor assigns a liberal number of carefully selected problems which are varied from year to year. The student should receive in this connection considerable drill in the use of steam and other physical tables.

Thermodynamics requires a certain amount of mathematical perception, but the necessary mathematics does not extend beyond calculus and is of a very simple nature. The difficulty experienced with thermodynamics by engineering students is not due to the mathematics or to the facts involved but mainly on account of the character of the text books available. Students complain that the subject matter in thermodynamics text-books is not presented in a clear and definite manner. Many of the instructors are of the opinion that the existing text-books are either too mathematical and abstract or so much predigested as to leave but little opportunity for a student to exert much effort. If to write a good text-book on pure thermodynamics was as easy as to criticize the existing text-books the above-mentioned difficulty could be easily overcome.

Some teachers are of the opinion that much can be gained by using two text-books, one of which takes up the subject from the mathematical side and the other mainly from the non-mathematical standpoint. A good combination can be formed by such text-books as Goodenough's and Ennis's or the abridged edition of Lucke's. It will not be possible to cover both books from cover to cover, but the viewpoint of the student will be broadened and his grasp of the subject improved by using two books. If the whole course must be given out of but one text-book, supplementary references should be assigned to other books.

In discussing this matter with teachers of the subject, I found nearly everybody dissatisfied with the existing textbooks, and the majority planned to improve upon them. The textbooks on the subject are changed every year.

The symbols used in thermodynamics text-books come in for some share of the blame. Some writers of text-books make the subject more difficult by the use of new symbols. As an illustration, ϕ, N and S are the symbols used by different writers to denote entropy; latent heat is denoted by the symbols L and r by the two leading authors of steam tables. Uniformity of symbols for thermodynamics would prove very advantageous. In Volume V of the *Proceedings* of the S. P. E. E. a very excellent report upon the "Uniformity of Symbols" was presented by a special committee. In this report the committee recommends the restriction of the significance of each letter or symbol to a single meaning in a single subject. The author of one of the best text-books on engineering thermodynamics does not use "too binding symbols, preferring to compel the occasionally reluctant reader to grub out roots for himself—an excellent exercise which becomes play by practice." With the limited time available for important subjects, I hardly agree with the above practice.

Uniformity in symbols for thermodynamics should prove very advantageous and it is hoped that the committee of the S. P. E. E. on the "Standardization of Technical Nomenclature" or a new committee will consider symbols for the various branches of the engineering profession.

The laboratory practice accompanying a course in pure thermodynamics should include experiments on the flow of gases and vapors, use of gas and steam calorimeters, evaporation tests on boilers, thermal efficiency tests on steam and internal combustion engines, air compressors and refrigerating machinery. The laboratory experiments in connection with a course in pure thermodynamics should bring out the limitations of various prime movers and other power plant apparatus.

3. *Senior Year—First Semester.*—Power plants—lectures and recitations, one hour per week. Laboratory and drafting room practice, three hours per week for electrical engineering students and six to eight hours per week for mechanical engineering students. (Two credit units for electrical, and three and one half for mechanical engineering students.)

The class-room instruction should include a study of the economics of steam-electric and gas-electric power plants including power plant specifications.

Several of the laboratory exercises may be devoted to complete power plant tests, but the major part of the time should be given to the power plant design, including a study of load conditions, location of plant, location of prime movers, and auxiliaries and similar details.

Such subjects as steam-engine design, gas-engine design and boiler design should be taken up in connection with machine design. These courses should either precede or be given at the same time as the course in power plants. In any case thermodynamics and strength of materials should be made the prerequisites to a course in heat engine design.

4. The remaining four credit units for the mechanical engineering students should be devoted during the second semester of the senior year to refrigeration, compressed air and heating and ventilation.

5. The instruction in thermodynamics and its applications to civil engineering students should be given during the second semester of the junior year or during the first semester of the senior year. Four and one third credit units, the equivalent of 3 per cent. of the total points in the civil engineering course, should be divided into three hours of class-room instruction and four hours of laboratory practice per week.

TIME DEVOTED TO ENGINEERING THERMODYNAMICS IN AMERICAN COLLEGES.

Name of Institution.	Per Cent. of the Total Credit Hours.		
	M.E.	E.E.	C.E.
1. Alabama Polytechnic Institute	7.9	5.7	—
2. Armour Institute of Technology	10.2	3.0	1.2
3. Brooklyn Polytechnic Institute	18.4	5.5	3.7
4. Case School of Applied Science	13.0	2.3	—
5. Carnegie Institute of Technology	11.0*	3.7	3.0
6. North Carolina A. and M. College	14.6	3.8	—
7. Cincinnati University†	6.1	5.6	—
8. Clarkson College of Technology	13.1	10.3	2.0
9. Clemson Agricultural College	6.0	6.0	6.0
10. University of Colorado	9.8	5.6	1.4
11. Columbia University†	14.8	4.1	2.6
12. Cornell University	14.3‡	12.3	2.0
13. North Dakota Agricultural College	15.7	—	3.0
14. South Dakota State College†	6.0	3.7	—
15. Delaware College	14.5	7.3	—
16. University of Florida	6.0	3.7	—
17. Georgia School of Technology	9.8	3.8	2.7
18. Idaho University	16.4	5.3	3.3
19. University of Illinois	10.3	4.4	2.2
20. Iowa State College	11.9	3.5	2.1
21. Iowa State University	18.5	5.2	3.7
22. Kansas State Agricultural College	14.0	6.2	2.0
23. University of Kansas	9.0‡	6.5	2.2
24. University of Kentucky	10.0	10.0	—
25. Lehigh University	13.3	3.8	1.9
26. Leland Stanford University	13.3	13.3	5.0
27. Massachusetts Institute of Technology	11.7	8.5	5.1
28. University of Maine	11.0	4.7	—
29. Michigan Agricultural College	12.5	12.5	5.4
30. University of Michigan	10.0	—	—
31. University of Minnesota	10.3§	5.6§	—
32. University of Missouri	9.3‡	2.0	2.0
33. University of Nebraska	20.8	5.6	5.6
34. University of Nevada	8.3	8.3	—
35. New Hampshire State College†	15.7	8.2	—
36. New Mexico A. and M. College	12.2	9.0	3.2
37. New York University†	11.8	—	1.8
38. Northwestern University	5.5	5.5	1.7

* Eleven per cent. of the total time is devoted in the steel works option. This is increased to 20 per cent. in the power option at the Carnegie Institute of Technology.

† Figures not checked by professor in charge.

‡ Required units; additional courses in thermodynamics may be elected.

§ These figures do not include the post senior year. Including the post senior year the percentage of credit hours devoted are 15.82 and 6.64 for the mechanical and electrical engineering courses, respectively.

Name of Institution.	Per Cent. of the Total Credit Hours.		
	M.E.	E.E.	C.E.
39. Ohio State University	7.7	2.0	1.3
40. Oklahoma A. and M. College	7.1	3.8	—
41. Oregon Agricultural College	19.0	10.3	—
42. Pennsylvania State College	14.6	6.4	3.1
43. University of Pennsylvania	11.6	5.9	2.0
44. University of Pittsburgh	10.7	2.1	1.2
45. Purdue University	13.3	2.8	2.3
46. Rhode Island State College	10.3	6.7	3.9
47. Rose Polytechnic	10.7	7.1	3.6
48. Rutgers College	11.3	6.3	—
49. Stevens Institute of Technology	12.4	—	—
50. Swarthmore College	7.0	2.8	2.1
51. Syracuse University†	15.2	11.0	1.8
52. University of Tennessee	10.4	6.5	—
53. Texas A. and M. College	12.6	7.6	2.7
54. University of Texas	—	8.0	6.4
55. Throop College of Technology	9.6	4.9	1.0
56. Tufts College	12.1	5.7	2.1
57. Tulane University	17.4	17.4	3.4
58. Union College	—	4.2	2.0
59. Vanderbilt University	13.2	11.0	2.2
60. University of Vermont†	7.8	5.2	—
61. West Virginia University	10.4	10.4	4.5
62. Washington State College	11.2	5.0	—
63. University of Washington (Seattle)	17.0	3.0	—
64. Washington University (St. Louis)	16.8	3.9	2.6
65. University of Wisconsin	11.1	5.2	2.6
66. Worcester Polytechnic Institute	9.7	7.6	3.2
67. University of Wyoming	17.6	11.2	—
68. Yale University†	16.1	8.1	3.2
Average	11.8	6.5	2.9

A text-book should be used which includes brief descriptive details of steam and internal combustion engines as well as the elementary principles of pure thermodynamics. The writer found Allen and Bursley's "Heat Engines" very satisfactory in a course for civil engineering students.

The laboratory practice of this course should include: standardization of instruments, indicator practice, use of calorimeters, valve setting, brake, economy and thermal efficiency tests on steam and gas engines.

6. Special courses in compressed air, water gas manufacture, steam turbines, internal combustion engines, and advanced thermodynamics should be offered as electives during the senior or postgraduate year.

METHODS OF TEACHING INDUSTRIAL MANAGEMENT AT THE UNIVERSITY OF KANSAS.

BY P. F. WALKER,

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During the past ten years scientific management has become a very common word in technical engineering literature. In this and in equivalent forms it has come to represent a distinctive kind of work within the scope of the engineering profession which has meant much in the development of industrial efficiency in those establishments where it has received the most careful attention. While this work has been going on among the organized manufacturing establishments of the country, the engineering schools have in many cases felt the need of doing something to advance the cause and to assist those who are in training for the profession, so that they may enter upon their life work with a knowledge of fundamental principles which will enable them to attack more readily the problems of production. Many of us in the schools have been somewhat uncertain as to the extent to which we should go in this new direction, and probably there is no single group of scheduled courses which has received attention so varied, and perhaps none in which the treatment has been more unsatisfactory when considered as a whole. If we are frank we will admit that these courses, dealing in a large measure with the human problem of management, hold a position in the educational plan which is inadequately defined. As we emerge from the first decade of experience with this element, it would seem that we should be in a position to take a definite stand and at least begin to bring it into some condition where its connection with other work may be fully recognized.

Terminology has an influence in such matters. It does make a difference by what name we call an article or principle, as to the interpretation which we give to it, as well as to the thing itself. In this connection we find running through the current technical press, as well as through current technical school catalogs, a variety of names, all referring to this same general subject. These names are: scientific management, efficiency engineering, works management, industrial engineering, plant administration, industrial organization, engineering economics, and others. So varied is this galaxy of names that it is difficult sometimes to interpret catalog titles and course descriptions. Each man who attacks the subject considers himself at liberty to use the name which seems to him to fit most accurately his conception of the work which should be carried out in order to make definite the application of the scientific method to the varying complex problems involved in the management of industrial plants. The time may be ripe for some initial effort directed toward the bettering of this situation, but that is not the purpose of the writer at the present time. It is the thought now rather to suggest the method of coördination of technical and administrative principles in the teaching of certain well-established subjects, common in the curriculum for mechanical engineering.

At the same time that we are considering the conditions which make for industrial progress in these lines for which students are being trained, it is necessary to consider our educational ideals and the needs of the man who is receiving the training. The manufacturing industries are needing men who are competent to direct their affairs in the most effective manner possible. We say that the manner which is most effective is the scientific one. Correctly or incorrectly, many are assuming that this need constitutes a call on the engineering schools and colleges for men who have received a training which will enable them to perform this work. However it may be with respect to the industry and its needs, the fact remains that the schools are educating men for life work in lines which we designate as engineering. Engineering is an elastic term, however, and there is no objection to our considering that it is being made to cover a new line of activity represented by the management function. This is not the point at issue. The main thought is that we are training men to meet the varying demands of the industrial world while at the same time they are being educated in a definite systematic manner, and we cannot afford to adopt the practice of giving experience in the school in the specific routine of duty involved in the management function in any greater degree than we may include exercises in the routine of other purely technical phases of engineering practice. Just as we scan the work of shop and drawing room and laboratory and clear away the rubbish of purely manipulative exercises in order to make every hour of the student's time effective in his true development and training, so must the work in this new line be reviewed with painstaking care that what remains in the course of study may be of real significance in the development of sound fundamental principles which will be of universal application. Our schools cannot afford to lose time in pursuit of any illusive will-o'-the-wisp, and be the cause of our students' spending their time in learning systems which must be unlearned at a later date when time means prestige as well as money.

The principle of growth is one which is vital in this as in all other phases of educational experience. It is not an accident that the period of school training is set for the years of life of the boy when mental growth is still rapid but coming to the stage preceding the formation of a definite system of thought and action. The future career of the engineer-to-be is dependent upon his continued growth and not upon the amount of his absolute knowledge at the end of this period of training. In the industrial world also, business conditions of the present day developed from conditions of the past and future conditions will develop from the present. Here as elsewhere the law of growth is in evidence. Foundation principles and not finished systems will characterize the material which the successful teacher presents to the students in the field of management as truly as in the field of pure science. We employ, it is true, fixed methods for the carrying on of specific investigational work in our laboratories and it is important that enough of such methods should be instilled into the student in order to establish that which we call the scientific method. The successful laboratory teacher does not stop here, however, but makes clear that this method which is being insisted upon is a means and not an end; that the true end in view is the determination and control of facts, and the interpretation of those facts as elements in the development of real industrial problems. The engineer is broader than the technologist and it should be true that the highest ideals are fostered in the school, which should stand behind him and furnish inspiration for continued effort. It should not be necessary for him to discover in after years that he needs to view his work as something having to do with the welfare and development of society at large through business and economic systems. These ideas should be implanted in him at that period in his life when he may take advantage of all opportunities and direct his own development and growth so that he may exercise the broadest influence possible within his sphere of action. This result does not come from the inclusion of a few detached types of courses in the engineer's training, under titles which indicate a bearing upon scientific management and economic problems. To spread material like this over the rough framework of rigidly technical courses accomplishes but little. The engineering student's work in technical lines should be saturated with the idea that every technical problem has a commercial significance. A design of a machine or structure is not a completed problem unless the elements of cost and serviceability in operation have been considered and compared with other possible designs. In the symposium on scientific management held at the Boston meeting of the Society in 1912, one of the speakers struck the significant note which is fundamental to the idea now before us. Quoting from that paper.* "Unless a machine can be built at a cost sufficiently low to meet the demand it will never get beyond the experimental stage and there is absolutely no use in designing a machine if its cost of production or operation exceeds what can be properly paid. It is certainly important to teach the student how a bar can be turned round on a plate made flat or how every operation necessary to making a machine may be carried out by a mechanic; but it is equally important that he should know their relative costs so that he may avoid the expensive operations or reduce their use to a minimum. He should also be taught that the maximum economy in producing that machine will result when it is made in quantity, and why; and that quantity production will involve changes in design; changes in shop processes because it permits the use of special instead of standard tools; and finally and most important, that quantity production involves many men and that many men require management that each may produce the maximum for his wages, and that such an organization for economic production is subject to laws and principles of far greater consequence than all the thermodynamics that was ever formulated, these laws being of essentially the same nature as those that control the design of his machine.''

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* "Teaching Scientific Management," by Walter Rautenstrauch.

In the mechanical engineering curriculum which is characteristic of all of our established schools, primary emphasis has always been laid upon the technical elements of design and construction of machinery and upon the theory of heat engines and other forms of power apparatus. The developments of the last decade have impressed upon our minds the fact that an important portion of the mechanical engineer's time must be devoted to the devising and perfecting of manufacturing processes. In the operation of plants of numberless variety as well as in their initial design, there arise many problems for him to solve. The greatest ultimate economy, or maximum over-all efficiency, is being sought for. In this there are involved all of the questions surrounding the application of invested capital to the manufacturing business and the adjustment of raw material and labor supply to a shifting market. In the design of a new plant, in the selection of its equipment of both primary and secondary type, as well as in the fixing of the organization for its operation and accounting functions, the engineer must bring to bear his understanding of business conditions, of the influence of locality, of technical elements in process and equipment, of power and its application, and of the human element in the industries. The competition of modern business, which is the challenge for efficiency, is calling for a new type of engineer, whose duties are forcing him gradually into a position of control over all phases of the industry.

If this is true we can not ignore it in the schools. The new demands must needs be met. How to meet them has been and still is the problem. There are questions involved which are fundamental in character but which from the standpoint of their application in industry must supplement the fundamental physical sciences. These principles must govern in the development of the applied sciences and they go far in determining the conditions under which science will meet most effectively the needs of society. It is not that these new elements should predominate or that there should be any relaxation in the treatment of the technical elements in design and heat-engine theory. It means simply that the scope of our work must be widened to include many industrial processes outside of machine manufacturing, and that there must be a more accurate balancing of machine theory with machine value in production. In a very specific sense the engineer accomplishes his results through the use of equipment which is largely of the machinery order, and the essence of the new idea in industry is that consideration of the methods employed in the use of equipment is to be given a place of importance equal to the principles on which the equipment is constructed. The prospective engineer should be taught to study the machine as an agent and not as an end.

At the University of Kansas effort has been made to bring the work which is required of mechanical engineering students in accordance with the general ideas which have been expressed. Two years ago the curriculum was revised and many sweeping changes made in this as in other group requirements for the bachelor's degree. In fixing upon the amount of work to be required, a working week of fifty-one hours was adopted on the basis that each hour of credit should call for three hours of actual time by the average student. In scheduling individual courses each hour of regular class work is expected to require two hours of outside preparation, while in other courses either two hours or all of the three hours may be scheduled for work under the instructor's supervision. This means that seventeen credit hours constitute the average enrollment and that one hundred and thirty-six of such hours would be completed in four years of two semesters each. To this number have been added two additional credits for work done at non-schedule hours, such as the writing of special reports on technical topics. It is assumed also that summer vacation work may be required during two years or that in lieu of this the student may be required to do work to the extent of one or two additional hours. It thus comes about that the mechanical engineering curriculum includes one hundred thirty-nine credit hours and one period of summer vacation work.

Out of the one hundred thirty-nine hours, thirty-nine are in technical subjects taught by members of the mechanical engineering department staff. Of these, fourteen hours are in the field of mechanism and design; twelve hours are in heat engineering; six and one half hours are in laboratory practice, this including the time devoted to professional thesis but not that given to hydraulic and electrical work; and six and one half hours in courses listed under topics which would be considered to be in the administrative and management group. It should be said for the information of those who might be checking this by the catalog, that of the latter group five hours are not listed under the head of mechanical engineering but have been transferred to a new group under the general head of engineering. The subjects thus referred to are taught by a member of the mechanical staff.

A further analysis of the work included in these several groups reveals the following conditions. Out of the twenty and one half hours given to designing and laboratory work, ten and one half hours are of such character that it has been possible to include in them so much of a study of economic conditions, relating to control. operation. up-keep, and output. that they may be said to bear in very considerable measure upon this kind of training which we have under discussion. In a similar manner. out of the six and one half hours scheduled under topics suggesting management principles, approximately four hours of the time are devoted to the discussion of matters which are either purely technical or belonging to the field of business economics and contract law. This means that out of the total only two and one half hours may be said to be given to specialized management principles in differentiated courses, while even that can hardly be said to be separated from purely technical matter. The remaining four hours of this latter group. combined with the ten and one half before mentioned. constitute a secondary group of fourteen and one half hours in which the consideration of economic production and value of equipment as a producing factor are included among the important principles. It may be said, therefore. that in the work of one semester out of the eight which constitute the complete period of study, the student is uniting technical elements in design and investigational work with the ideals and methods of scientific management. To this should be added some fraction of the time given to heat engineering, in which the question of adapting design and types to economic conditions is given much attention.

A brief resume will now begin of the specific courses in which management ideas receive most direct consideration. In fixing upon the field to be covered an attempt has been made to avoid the limiting of the work to a consideration of purely machine building enterprises. The time given in most of our schools of engineering to the shop practice work has had a tendency to focus the attention of students and instructors alike on work of this character and it is important that other branches of industry should come in for consideration. The first course is introduced during the latter half of the junior year. It is the one course among the three included in this group, which has direct bearing upon machine manufacturing and it follows immediately in our schedule the last of the shop practice courses. The title given to it is shop methods. One and one half hours of credit are given for the work which is laid out on the basis of thirty-two class periods, one half of these being of one hour duration for discussion and recitation on material covered by reading in assigned topics, and the other half being three-hour laboratory and drawing periods. The work may be classified under five heads as follows:

(*a*) *Records.*—This includes discussion and practice work on the keeping of records of men, of producing machines, of material, of labor time, and of production, each of the first four being related finally to production. It is in reality a study of the output of individual men and machines, together with the determination of the fundamental data for determining direct costs. The students have just completed their own shop practice work and are now made to see the necessity for the keeping of direct records. It should be said in passing that in all of their preceding shop practice work, with the possible exception of the most elementary beginning courses, they have been engaged on work for which estimated time has been set and on which they have been required to keep their own time and make comparisons to show how nearly they have succeeded in reaching standards of performance. This is merely a study of methods. Eight periods are given to this work.

(*b*) *Routing of Work.*—In this the men are made to consider how machines should be arranged in order that material may move freely and continuously through the plant. A few sketch drawings are made and the questions of technical requirements in actual operations demanded for the business under consideration, and of performance of individual machines. are considered, parallel with the question of effect of location of machines on cost of handling. Six periods are given to this work.

(*c*) *Tools.*—The work given under this heading may be divided into two groups,—small tools and machine tools. In both of these subgroups the work is largely of informational character. Students are required to go to manufacturers' catalogs and make a close study of what is available on the market. In most cases a considerable number of tools will be found, each meeting the needs for the one particular process under consideration, and it becomes the duty of the student to consider adaptability, first cost, probable depreciation, and special design in the more elaborate tools effecting applicability. The consideration of the elements to be considered in the selection of tools for a given work is a primary consideration. Ten periods are assigned to this work.

(*d*) *Time Study.*—Very brief consideration is given to this, the proposition being to make clear to the student the fact that a detailed study of operating time may be essential in many cases. He is required to do considerable reading in order that he may become familiar with established practice and he is then given a small amount of practical work in timing the operations of another student engaged on a particular task. From the data thus secured he prepares an instruction card. Four periods only are given to this work.

(*e*) *Cost Accounting.*—In this work the student summarizes the data considered in section (*a*) and takes up the question of the distribution of indirect expenses, incident to the usual shop operation. The individual study under sections (*b*), (*c*), (*d*) has served to familiarize him with certain elements of indirect cost, such as cost for depreciation of equipment, superintendence, power costs, and various other items. Standard forms are used when applicable. Four periods are given to this work.

In the first semester of the senior year the men who have completed the shop methods are taken into a two-hour course under the title of manufacturing. This is a combination study of the processes employed in various manufacturing industries and of economic principles underlying the commercial development in those lines. The condition of business in such branches as the textiles, leather, paper, and others are examined with reference to the increased value of material due to the process and the relative magnitude of costs of material, labor, power, and transportation. In a rather specific way the question of power and of methods of its application is dealt with, together with problems which must be met in the selection of power apparatus and other equipment. In the main it may be said that this course involves more that is technical than of that pertaining to management, being devoted more particularly to adaptability and selection of equipment than to the details of operation.

Following this work there comes in the second semester of the year the three-hour course in industrial administration. The ground covered here includes a brief history of the industrial development of the modern period, a brief line of discussion in corporation finance, and the principles of contract law, followed by a study of the fundamental elements of cost of production and methods of determining depreciation of equipment. The order of development of the plan for management courses is somewhat illogical at this point, since all seniors in the school of engineering take this course, while only the mechanical engineering students have taken the preceding ones. The several courses are coördinated, however, so that there is but a slight amount of duplication for the mechanical students. About one half of the work of the course is in contract law and similar topics, and in this way it is made to replace the special course in contracts given at most institutions.

Another course optional for mechanical engineering students and which is elected by most of them, is given during this second semester and is a logical sequel to the one in manufacturing. It is mainly a design course and hence is listed in that group rather than in the special administration group. It is catalogued under the title of industrial plant design, for three hours credit. In it the student develops in detail a plant in which to carry out some manufacturing process or power development work, bringing to bear in a specific manner all of the principles which he has acquired in the preceding courses. In it he gives much attention to the physical characteristics of the plant, including buildings and local transportation facilities. While technical in its main features, it is a fitting culmination for the work devolving upon the engineer-administrator.

As has been suggested before, there are various other courses in the lines of designing and laboratory investigation in which attention is given to the element of economy in construction and in operation. In the reference made to it, it was stated that in the ten and one half hours devoted to these branches, this attention is being given in a marked degree. The three hours in industrial plant design just mentioned in detail are included in the ten and one half hours. It is the belief of the writer that engineering laboratory courses of the more advanced character should deal with engineering problems of the research type rather than with specific laboratory exercises. Upon this basis the teaching of such branches becomes one of the most difficult lines of work in the entire engineering curriculum, and requires men of ripe experience rather than young instructors.

In this same connection there is offered a most fertile field for thesis work. It will assume naturally the form which bears largely on the technical, but when it is carried out under the supervision of instructors who have a vision of combining the technical with the commercial there is opportunity for successful work directed toward the end in view. This is a point, however, which is dependent largely upon conditions which are sure to develop as local circumstances dictate, and it is not the thought to press this point to any undue extent. There exists here, however, the possibility of maintaining that adjustment of conditions which will assist the engineer in distinguishing between that which is an end in itself and that which exists as a means to an end.

It is not assumed that the method which has been outlined is the only one by which there may be brought about coördination of instruction in the technical branches of applied science with the fundamental principles of industrial administrative work. Very likely it is not the best method which may be devised. No statement of ideals and purposes, and no particular combination of scheduled courses, will produce exactly the same results when applied under two varying situations or conditions, or under different groups of men. Results in matters like these are conditioned by the differing shades of emphasis which will be given by instructors of varying personalities. The fundamental point at issue is that there is a well settled belief in the minds of many that in professional practice the engineer-manager cannot differentiate his duties as manager from his duties as engineer. He must deal with men and with processes at the same time that he deals with physical equipment. While the school training is not expected to cover every point of professional practice, it is submitted that, that which is done in the attempt to cover this phase of the engineer's work should be done in accordance with the conditions under which that work is to be done. The final result of this or any other method of dealing with the problem will be determined by the test of time.

WOODWORKING FOR MECHANICAL ENGINEERING STUDENTS.

BY A. S. KINSEY,

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In these times of rapidly changing methods of manufacture and new ideas in shop practice, all of much importance to engineering graduates, is it well to have a student in a college shop course spend weeks of time at woodturning? Should he be allowed to stay another prolonged period at bench carpentry, and then continue tediously along through a number of exercises in patternmaking? How much time, all things considered, should a mechanical engineering student be required to give to woodworking as it is at present being taught in many college shops?

These questions have frequently found place in the mind of the writer. and such conclusions as have been reached so far come largely from observations made during fifteen years of commercial experimental engineering carried on in many of the best shops and manufacturing establishments of the country, where the character of the shop work required of engineering graduates employed in such plants could be carefully considered.

The usual college wood shop course for mechanical engineering students consists of woodturning, bench carpentry and patternmaking. In some instances woodturning does not receive special recognition, but is treated as part of patternmaking. It would seem to be possible to replan this schedule so that in the same amount of time a woodworking course can be given which will result not only in getting a little nearer to what would be most useful to the engineering graduate, but also stimulate the interest of the student who, while usually well occupied with the woodturning jobs, is likely to show an indifference toward his work in carpentry and patternmaking?

At Stevens Institute of Technology the courses of the department of shop practice are all given in the freshman year, the total time allotted to the work of all shops being 288 hours. Of this amount one third, or 96 hours, is given to woodworking. On first thought this may seem a small amount of time in which to try to accomplish what should be expected of such a course. From another point of view, however, the very brevity of the course may be made to serve as a stimulus toward an intensive type of work which might be productive of an efficiency greater than that usually obtained from a more extended schedule. Workers of this kind are, of course, expected to be able to differentiate between rational speed and hurry.

Another important factor for consideration has been the necessity of starting the student at the most elementary type of woodworking, because of his lack of previous training. A canvass of the present freshman class at Stevens, now numbering about 160 men, shows that only 31 per cent. of the members had instruction in woodworking in high school, that 33 per cent. had received a short course in elementary woodworking while in the grammar school, and that 36 per cent. had never had any instruction in woodworking before entering Stevens. And as many of those included in the 31 per cent. had been given only a short course in the subject while in high school, it has been found necessary to start more than 95 per cent. of the class at first principles. The following course has, therefore, been worked out, and is now in operation at Stevens (see Fig. 1).

Bench Carpentry.—In this branch of the work it is intended that the student should have about time enough to become familiar with the ordinary hand tools and the first principles of wood construction. The time allowed permits of the following work being done:

Job 220: Jointing, setting and filing a cross-cut and a rip saw. (See Fig. 2.)

Job 221: Making a whitewood saw-board, teaching sawing and planing.

Job 222: Making a white pine drawing board, teaching jointing, glueing, and how to provide against shrinkage and warping.

Job 223: Building a 12 in. x 18 in. single-panel door of oak, teaching jointing, plowing, grooving, rabbetting, chamfering, wedging, framing, paneling, fitting hinges and lock. (See Fig. 3.)

These jobs may not differ essentially from those to be found in some other carpentry courses, but it is to be noted that in order to get the work done in the time allowed, sixteen hours, the student must give strict attention to the task at hand. Then before there is time for the work to cause his interest to lag, the subject is changed.

Machine Work.—Here is an opportunity to show the student how much more quickly wood work can be done by machinery than by hand. The men scheduled to go through this work are all started at woodturning. Then after a short time the instructor withdraws a team of two students from this group and puts them through a series of operations at the circular saw, hand saw, cylinder surfacing machine, universal tool-grinder, and the morticing machine. Explanations are given of the use of the different parts of the machines, and how they should be operated. The work at the woodturning lathes consists of a series of jobs to be found in common practice.

Job 200 is a molder's sprue, of ash or cherry, teaching centering, turning to dimensions, tapering, end-facing.

Job 201 is a handle for a socket chisel, of hickory or apple, teaching rounding, filleting, finishing and polishing.

Job 202 is a chain pulley of lignum vitae, teaching drilling, fitting to mandrel, turning to template.

Job 203 is a baluster of oak or yellow pine, teaching more difficult rounding, filleting, grooving and beading. (See Fig. 4.)

Job 204 is a ring of walnut, or mahogany, teaching chucking and template work.

Job 205 is a steel-stamp holder of maple or beech, teaching boring and jig drilling.

Patternmaking.—Practically all of the time allotted to this subject is given to the pattern and core-boxes for a 4 in. x 8 in. steam-engine cylinder. In this job the student is given a good opportunity to learn split-pattern construction, the use of draft, shrinkage and finish allowances, the value of filleting and the use of core-prints and core-boxes.

The work is preceded by a class-room lecture covering a description of patternmaking materials, the general application of patternmaking to practice, the use of wood and metal patterns, and the practice with plate and master patterns. At the close of the course a demonstration is given of the construction of plaster-of-paris patterns.

Wood Construction.—This division of the course is intended to bring out the mechanical principles of carpentry, and to show that a strong, safe, form of wooden structure can be obtained only when the timbers are well proportioned, correctly placed and properly fitted.

The accomplishment of this is first attempted by classroom lecture and printed notes, in which the attention of the student is drawn to the nature of the woods, to the distribution of the stresses through some typical systems of framing, and to a consideration of the strength of the wooden members of such construction. Then some representative practical applications of the principles involved are undertaken as jobs in the shop. Drawings of some of these jobs are shown in Figs. 5, 6, 7, 8 and 9. It will be noticed that these are not small bench exercises, but rather are full-sized jobs, using heavy timbers. Work of this kind invariably begets an enthusiastic interest on the part of the student. It is a man's task, quickly recognized as such, and undertaken with corresponding ambition and energy. It is the kind of work which might be expected of an engineer, and therefore must be worth while. We may theorize about the advisability of an *exercise,* but the student will prove the value of a *job* by the active interest he exhibits while at work on it.

Job 260, Fig. 5, is intended to illustrate a simple type of heavy construction, requiring laying out, jointing, fastening and bracing. Unlike the jobs of the other branches of the course, the joints do not need to be carefully chiseled, and in place of the customary glue and nails, the strength of fastening is obtained by lag screws and bolts.

In Job 261, Fig. 6, an effort is made to introduce a problem in simple trussing as found in ordinary floor beam construction. The work includes the setting of floor joists, trimming around a hatchway, jointing of beams and use of substitutes, bridging, and laying single and double floors. A header beam is run between two trimmer beams, one end of the header being fitted to the trimmer by a keyed tusk-tenon joint, giving the common strong and reliable form of all-wood joint, while the other end of the header is set in an iron stirrup to illustrate what is being done in modern methods of rapid construction. Tail-beams are fastened to the header by joints and stirrups, the bridging placed in position and then the flooring is laid in accordance with approved practice.

Job 262, Fig. 7, is intended to represent a common case of supporting loads over spans up to about 30 feet, jointing for specific strains, calculations of shearing joints, and the proper strapping of joints. The student's attention is directed to the particular strains to which the different members of the king-post truss are subjected, the necessity of using strong and properly proportioned lengths of wood, and the importance of the right shape of joint. The location of the joint is carefully determined, at least one by calculation, while the importance of keeping the joints tightly together is emphasized by the use of iron straps.

Job 264, Fig. 8, is a continuation of wood construction for supporting loads over long spans. It introduces the practice of splicing wooden members for heavy loads, and the proper proportioning of joints for tension, compression and shearing strains. This is obviously a better place in the course to teach the design of the spliced joints than in bench carpentry as exercises of reduced size, as was previously the practice in the Stevens shops.

Job 266, Fig. 9, illustrates methods of trussing beams and bracing overloaded floors. It shows the proper proportioning and ways of compounding wooden beams for trussing. splicing long beams for transverse loads, and the locating. fastening and use of iron struts and straining rods. There is not so much carpentry to be done in this job. but its value may be found in its solution of a construction problem common to many engineering graduates.

Each of the wood construction jobs is performed by a team of two students. While one team is busy on an A-frame, another team is building the king-post truss, another the queen-post truss and so on.

In starting the jobs each piece of timber is made as long as practicable, so that a number of teams can use the same lengths of wood by cutting them down. This of course, gradually reduces the size of the job, but the practice is not allowed to go far enough to spoil the proportions of the work. By the repeated use of the wood a proper economy of expense and of material is obtained. The cost of the jobs is also much reduced by sawing up and using the shortened timbers for woodturning.

A valuable feature of these jobs is the opportunity afforded the student to use a larger variety of tools, and of much heavier type than those usually employed in teaching woodworking.

Millwrighting.—To the writer's mind there is not a more valuable part of an engineering shop course than millwrighting. The ground it covers is often the first to be traveled by the technical graduate in the manufacturing plants. Its scope is broad, and while much time would be needed to thoroughly trace all of its branches, this should not be sufficient reason for entirely omitting the subject from a shop course. As many of the principles of millwrighting are to be found applied in wood shops, and as the other branches of college shop courses are likely to require all the time already assigned to them for other subjects, it has been thought best at Stevens to introduce this part of the work in connection with wood construction. The work covered consists of the erecting and alignment of a lineshaft; the setting of hangers, couplings, collars, and pulleys; the placing and leveling of machines in relation to the lineshaft, jackshaft and countershaft.

A study is also made of the use of different kinds of steel shafting; the power, speed, size and care of lineshafts, jackshafts and countershafts; of the various types of hangers, couplings, pulleys; and of chain, belt, rope and cable drives.

Carrying Along the Work.—The total time allowed for the woodworking course is 96 hours, which is divided as follows: Bench carpentry 16 hours, machine work 16 hours, patternmaking 32 hours, wood construction and millwrighting 32 hours. The largest number of students at work at any one time in the Stevens wood shop so far has been 40 men. These were maneuvered as follows: Group 1 of twenty men were started at bench carpentry, and group 2 of twenty men were put at machine work, beginning at the wood lathes. While an instructor was following up group 1, an assistant was starting all of group 2 at woodturning. Then after a short time the instructor withdrew a team of two students from woodturning to put them through a series of operations at the woodworking machines. These men were then returned to their work at the wood lathes, and a new team started over the same ground. After group 1 finished bench carpentry and group 2 machine work the groups were reversed, so that group 1 went to machine work and group 2 to bench carpentry. Then after 16 hours more a change of subjects put group 1 at patternmaking and group 2 at wood construction. When this work was completed the groups were again reversed so that group 1 went to wood construction and group 2 to patternmaking. While the men were at wood construction, they were withdrawn in teams of four to one end of the shop to go through the millwrighting course, which requires about 3 hours of time.

It may be noted that by this arrangement of schedule, while half the number of students were engaged at the benches, the other half were busy either at the lathes or doing wood construction jobs on the floor. This plan has made it possible to handle 40 students at a time with an equipment of 20 wood lathes, 20 benches, a circular saw, a band saw, a cylinder surfacing machine, a morticing machine and a universal tool-grinder. A hand-jointing machine and a disc sander should be added to this equipment.

In each branch of the woodworking course a class-room lecture is given to the group of students just before starting at the work, and these lectures are accompanied by duplicated notes for study and future recitation. There are no long demonstrations of the jobs in the shop corner with accompanying detailed explanations by the instructor to the whole group of students. Instead, each section while standing at a bench or machine, has a few brief directions given which are sufficient to enable the students to get started, and the instructor then follows up each man as he needs further help. The class-room lecture does not explain the way the jobs should be performed. It aims to make plain the nature and possibilities of the materials used and their application in practice, and to emphasize a proper consideration of the economy of design and of materials.

Each student is supplied with a blue-print drawing of the job, mounted on heavy book-board. This drawing shows, by a general view in the upper left-hand corner, an application of the job in hand to some well-known problem. The work to be covered is outlined in a column under the detailed drawings, while the tools required are listed to enable the student to learn their proper names. At the bottom of the plate are to be found some outlined directions. These are only sign posts. They do not take the place of the instructor, but they do tell the student what is to be done next, so that he does not need to be delayed, nor offer an excuse for idly waiting for an instructor; and while he will not know how to do all that the next move requires, he will be encouraged to help himself as much as possible. It has been surprising to see how much these directions do to keep a man moving along after he has been in the shop a few periods.

The woodworking course, like the other branches of shop work, is distributed over the three terms of the first year, the roster allowing 9 hours a week for the first term, 6 hours for the second, and 40 hours per week for the summer supplementary term. This last term is of special value, in that it provides for the student being in the shop a full working day of 8 hours, from 8:30 A. M. to 5:30 P. M., with an hour for lunch.

Examinations.—Regular written examinations are held in the classroom at the end of each term, and the following specimen questions may be of interest:

Name the three common stages of timber seasoning, give their percentages of moisture, and state to what extent the bending strength of a green board is affected when seasoned to the room-dry condition.

At what speed in r.p.m. should the spindle of a wood lathe run to turn a piece of soft wood 10 in. diameter?

(*a*) How should a circular saw be gummed? (*b*) What will make the saw heat up? (*c*) At what peripheral speed should the saw be run?

Why is it bad practice to overfeed a planing machine so as to slow down the cylinder knives?

State the advantages of the fillets and core-prints of a pattern.

It is required to cast a steel cylinder to be finished exactly to 12 in. diameter by 30 in. long. What should be the dimensions of the pattern?

(*a*) How is the stiffness of a heavy timber affected by doubling its width? (*b*) How much thicker would a timber have to be to withstand eight times its load?

(*a*) What is a safe center distance for the joists of a floor for heavy loads? (*b*) Would it be safe to place a machine weighing 5,000 lbs. with a base area of 4 ft. x 5 ft. on an ordinary wooden factory floor?

Sketch a wooden truss which might be used to carry a heavy load for a span of 40 feet, and also sketch the kind of joints that should be used to splice the straining beam and the tie-beam of the truss.

A 2 in. cold-rolled steel lineshaft running 250 r.p.m. was driving a 6 h.p. wood planer, a 5 h.p. circular saw, and twelve ½ h.p. wood lathes, and it was desired to add another 6 h.p. planer. Would the shafting carry the total load safely, allowing for friction losses?

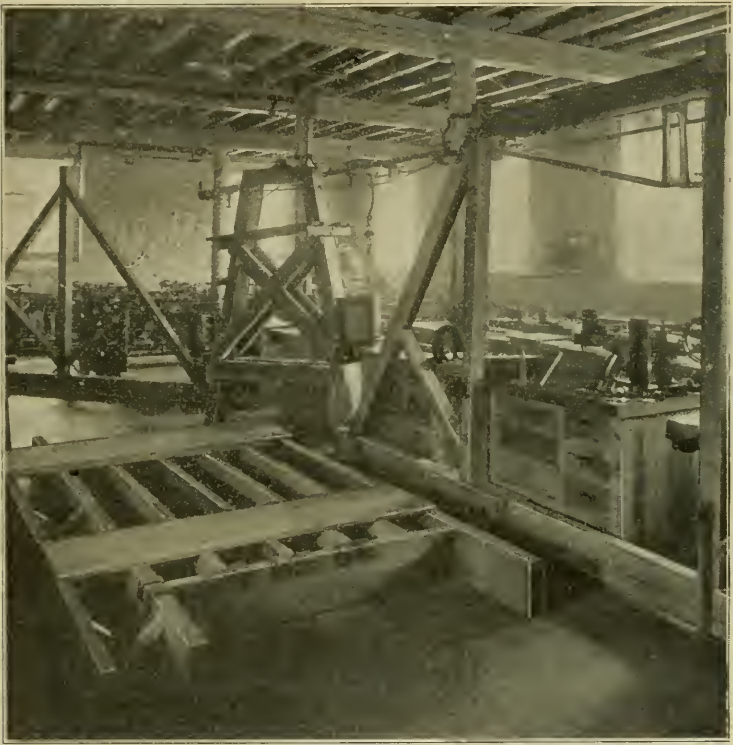


FIG. 1. View of One Side of Wood Shop at Stevens Institute of Technology, showing heavy wood construction and smaller jobs performed by freshmen.

Suppose a woodshop lineshaft was running 250 r.p.m., and a driving pulley on it was 16 in. diameter. Also suppose a 3 ft. grindstone had a 10 in. pulley on it. Would it be all right to belt the stone to the lineshaft?

If an idler pulley is to be used as a tightener on a woodshop driving belt running over a large and a small pulley, where should the tightener be located, and why?

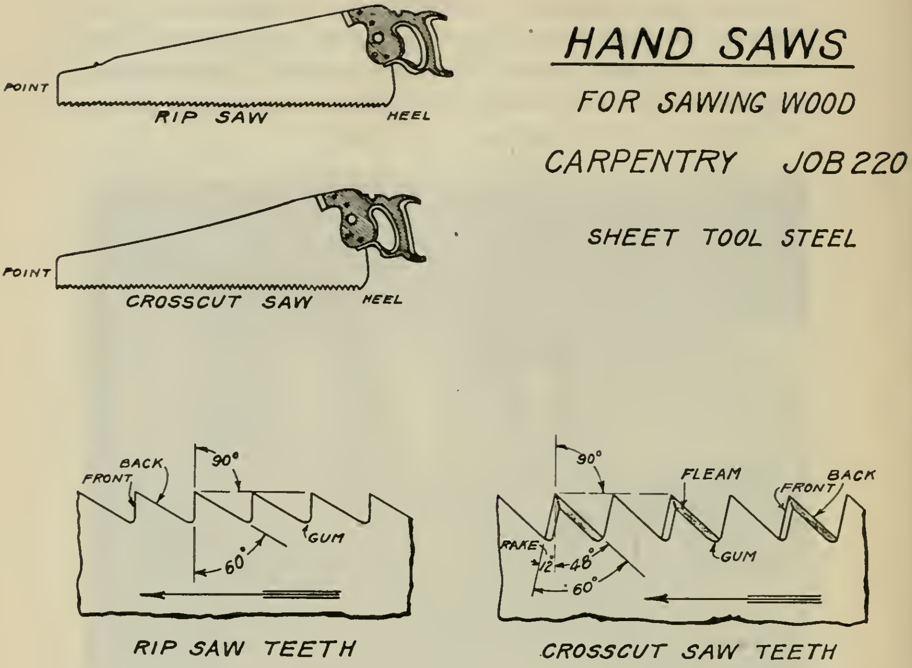


FIG. 2.

Work.—Jointing, setting, filing.

Tools.—From Tool Drawer: 2 ft. rule. From Tool Room: Cross-cut and rip saws, saw file, saw clamps, saw set.

Directions.—(0) Use given dimensions only. Rip Saw: (1) Place saw in clamps. (2) Joint the teeth by filing them down until they are all of equal height. (3) Set the teeth. Be sure that only the tooth and not the blade is bent. The maximum set should not go lower than half the length of the tooth. Just a little set for kiln dried hard wood, and the maximum for green soft wood. (4) File the teeth by holding the file horizontal and at right angles to the side of the saw. The front of the tooth is to be at right angles to the edge of the blade; the back at an angle of 60° with the front. Be sure saw is properly gummed, by using a hand saw file and not a three-square file. Cross-cut Saw: (5) Joint the teeth. See item 2. (6) Set the teeth. See item 3. (7) First file the teeth so that they have a rake of 12° and a back slope of 48°. Then file the fleam on the teeth by holding the file horizontal to the perpendicular of the side of the saw, on an angle of about 45° longitudinally with the length, measuring from file line toward the heel.

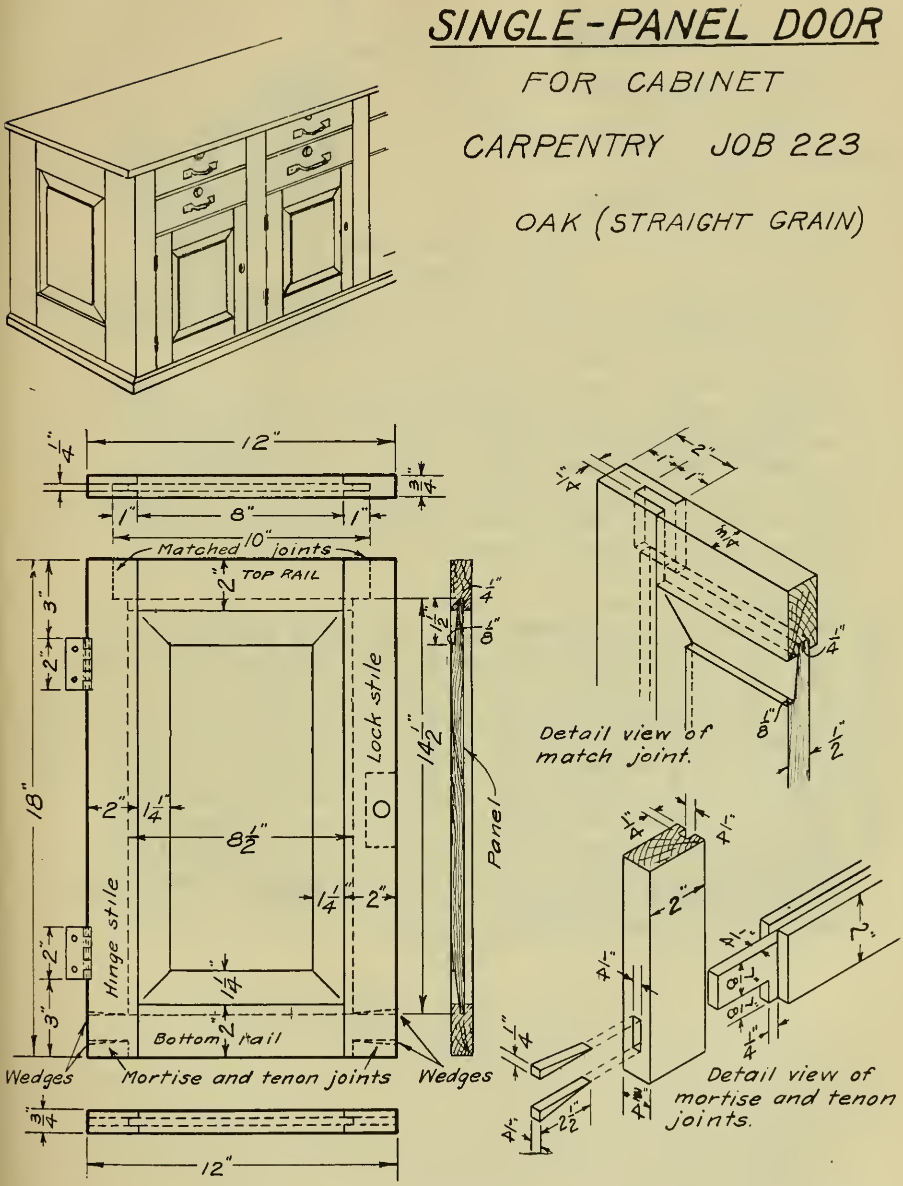

SINGLE-PANEL DOOR
FOR CABINET
CARPENTRY JOB 223
OAK (STRAIGHT GRAIN)
12"
1/4"
3/4"
1"
8"
1"
10"
Matched joints
TOP RAIL
2"
3"
2"
18"
2"
3"
1/4"
1/8"
1/2"
14 1/2"
Lock stile
Panel
2"
1 1/4"
8 1/2"
1 1/4"
2"
Hinge stile
1/4"
2"
Bottom rail
Wedges
Mortise and tenon joints
Wedges
3/4"
12"
2"
1"
1"
1/4"
3/4"
1/4"
1/8"
1/2"
Detail view of match joint.
1/4"
1/4"
2"
1/4"
1/4"
2"
1/8"
1/8"
1/4"
1/4"
2 1/2"
1/4"
3/4"
Detail view of mortise and tenon joints.

Fig. 3.

SINGLE PANEL DOOR

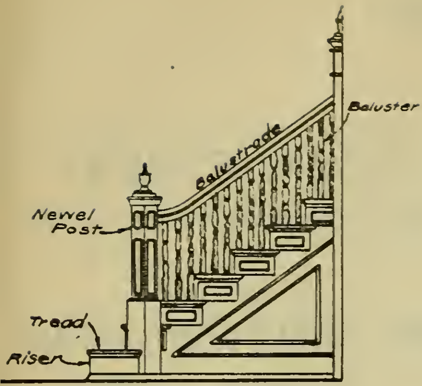
(Shown in Fig. 3.)

Material Required.—1 board 1 in. x 10 in. x 19 in.; 2 1½ in. x 2 in. W. I. butt hinges; 1 Wardrobe lock 1¼ in. x 2¾ in.; 1 board ⅝ in. x 9 in. x 15 in.; 4¾ in. No. 6 flat hd. screws; 4½ in. No. 4 flat hd. screws.

Work.—Match jointing, mortise and tenon jointing, plow planing—grooving, rabbet planing—chamfering, wedging—glueing, framing—paneling, fitting hinges and lock.

Tools.—From Tool Drawer: 2 ft. rule, jack plane, smooth plane, rip saw, cross-cut saw, back saw, 1½ in. paring chisel, ½ in. paring chisel, try square, marking gauge, hammer. From Tool Room: Plow plane, rabbet plane, ¼ in. mortising chisel, 3/16 in. auger bit, 5/16 in. auger bit, 10/16 in. auger bit.

Directions.—(0) Use given dimensions only. (1) Rip saw 1 in. board for the lock stile, the hinge stile, the top rail and the bottom rail. (2) Plane one side and one edge of stiles and rails. (3) Set gauge full and mark off and plane opposite side and edge of stiles and rails. (4) Make tongue and groove for matched joints at top of door. (5) Make mortise and tenon joints at bottom of door, cutting the hinge-stile joint by hand and the lock-stile joint by the mortising machine. Fit frame together. (6) Plow panel grooves in stiles and rails, using plow plane. (7) Plane both sides of panel to size and then saw and plane it to fit frame. (8) Chamfer panel to dimensions and place in position. Glue up door and wedge tenon joints. (9) Shoot the edges and finish sides of door. (10) Fit butt hinges and wardrobe lock to door. (11) Write check number on job and hand to instructor.



BALUSTER

FOR STAIR BALUSTRADE
WOOD TURNING, OAK YELLOW PINE
JOB No 203A

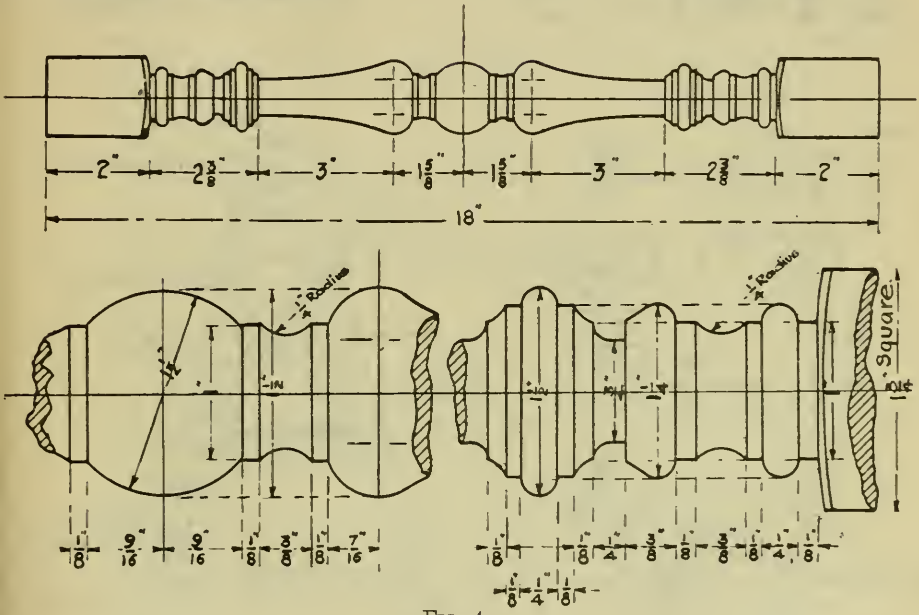


FIG. 4.

Material Required.—1 piece 2 in. x 2 in. x 19 in.

Work.—Rounding, filleting, grooving, beading.

Tools.—Gouge, skew chisel, parting tool, rule, round-nose chisel, dividers, calipers.

Directions.—(0) Work to given dimensions. (1) Begin at middle and rough down length to be turned. (2) Locate center of sphere. Starting at this point mark off on each side the principal dimensions. (3) Turn sphere, then working alternately on both sides, turn fillets, grooves and beads to proper dimensions. (4) Face off both ends to required length. Then finish with shellac. (5) Hand to instructor.

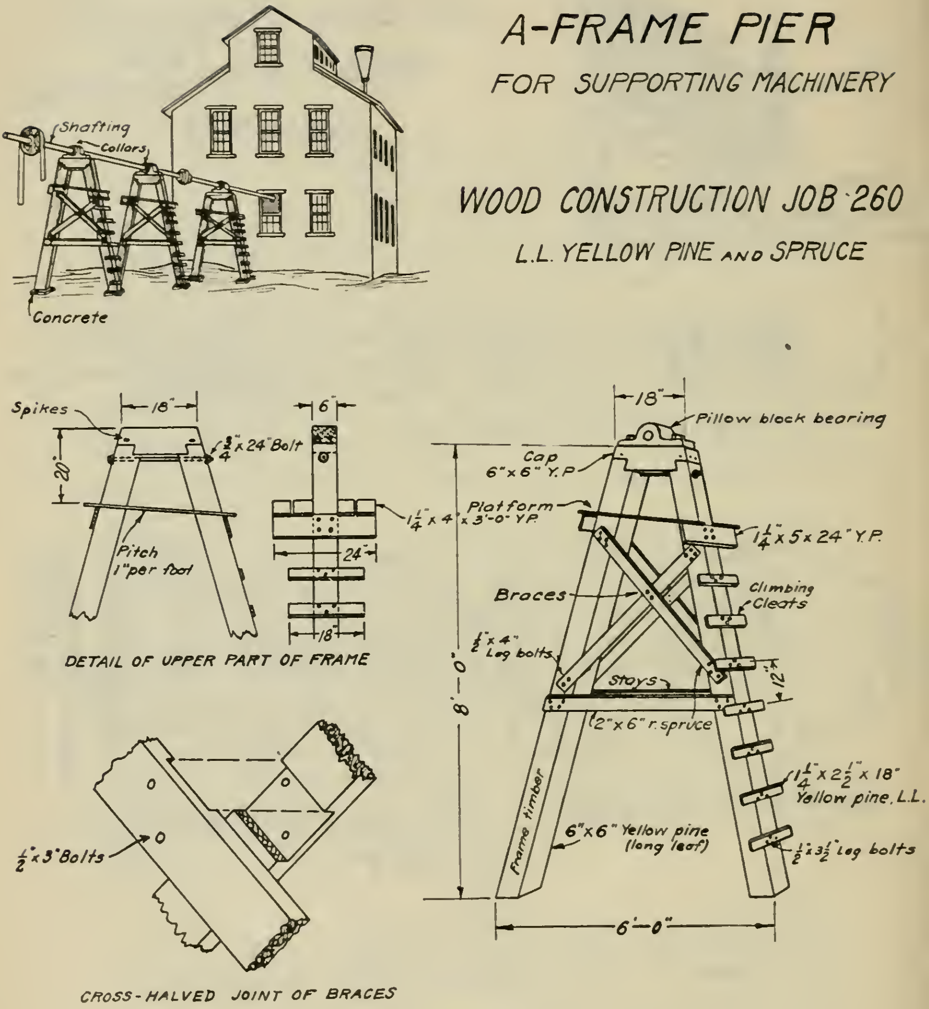

A-FRAME PIER
FOR SUPPORTING MACHINERY
WOOD CONSTRUCTION JOB 260
L.L. YELLOW PINE AND SPRUCE
Shafting
Collars
Concrete
Spikes
18"
20"
3/4 x 24" Bolt
Pitch 1" per foot
6"
1 1/4 x 4 x 3'-0" Y.P.
24"
18"
DETAIL OF UPPER PART OF FRAME
1/2 x 3" Bolts
CROSS-HALVED JOINT OF BRACES
18"
Pillow block bearing
Cap 6" x 6" Y.P.
Platform
1 1/4 x 5 x 24" Y.P.
Braces
Climbing Cleats
1/2 x 4" Leg bolts
Stays
12"
8'-0"
2" x 6" r. spruce
1 1/4 x 2 1/2 x 18" Yellow pine, L.L.
Frame timber
6" x 6" Yellow pine (long leaf)
1/2 x 3 1/2 Leg bolts
6'-0"

Fig. 5.

A–FRAME PIER

(Shown in Fig. 5.)

Material Required.—2 pcs. 6 in. x 6 in. x 8 ft. long-leaf yellow pine D4S* frame timbers, 1 pc. 6 in. x 6 in. x 3 ft. long-leaf yellow pine D4S* cap, 1 pc. 1¼ in. x 2½ in. x 12 ft. long-leaf yellow pine D4S* climbing cleats, 1 pc. 1¼ in. x 5 in. x 5 ft. long-leaf yellow pine D4S* platform support, 1 pc. 1¼ in. x 4 in. x 12 ft. long-leaf yellow pine D4S* platform, 3 pcs. 2 in. x 6 in. x 10 ft. spruce rough stays and braces, ¾ in. machine bolt and washers, 8 4 in. spikes, 16 10d.** (3 in.) wire nails, 2–½ in. x 2½ in. machine bolts and washers, 24 ½ in. x 4 in. gimblet-pointed lag bolts and washers, 20 ½ in. x 3½ in. gimblet-pointed lag bolts and washers.

Work.—Laying out, jointing and fastening, bracing.

Tools.—From Tool Room: 2 in. framing chisel, brace, 6/16 in. 8/16 in. auger bits, 14/16 in. ship auger, 1 in. adjustable "s" wrench, 12 in. monkey wrench, carpenter's pencil, 5 ft. folding rule, soapstone pencil, 8 ft. straight edge, 3½ in. lignum-vitæ mallet, 24 in. x 2 in. square. From Tool Drawer: cross-cut saw, rip saw, claw hammer, try square, T-bevel.

Directions.—(0) Use given dimensions only. Do not scale drawing. (1) Lay out angle of frame timbers full size on floor. (2) Lay off timbers and cap to proper angles and lengths. Bevel and check ends with cross-cut saw and 2 in. framing chisel. (3) Bore ⅞ in. hole for ¾ in. bolt through frame timbers, under cap. Place cap in position, tighten up bolt, and toe-spike cap to prevent lateral sliding. (4) Cut braces to proper length. Half-check with cross-cut saw and 2 in. framing chisel and bolt together. Then screw braces to frame timbers. (5) Cut stays to proper length and angle and screw to frame timbers. (6) Locate positions of climbing cleats and platform supports and screw them to frame timbers. Nail platform in position. (7) Fasten pillow-block in position on top of cap.

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* dressed 4 sides, ** 10-penny 3 in. long.

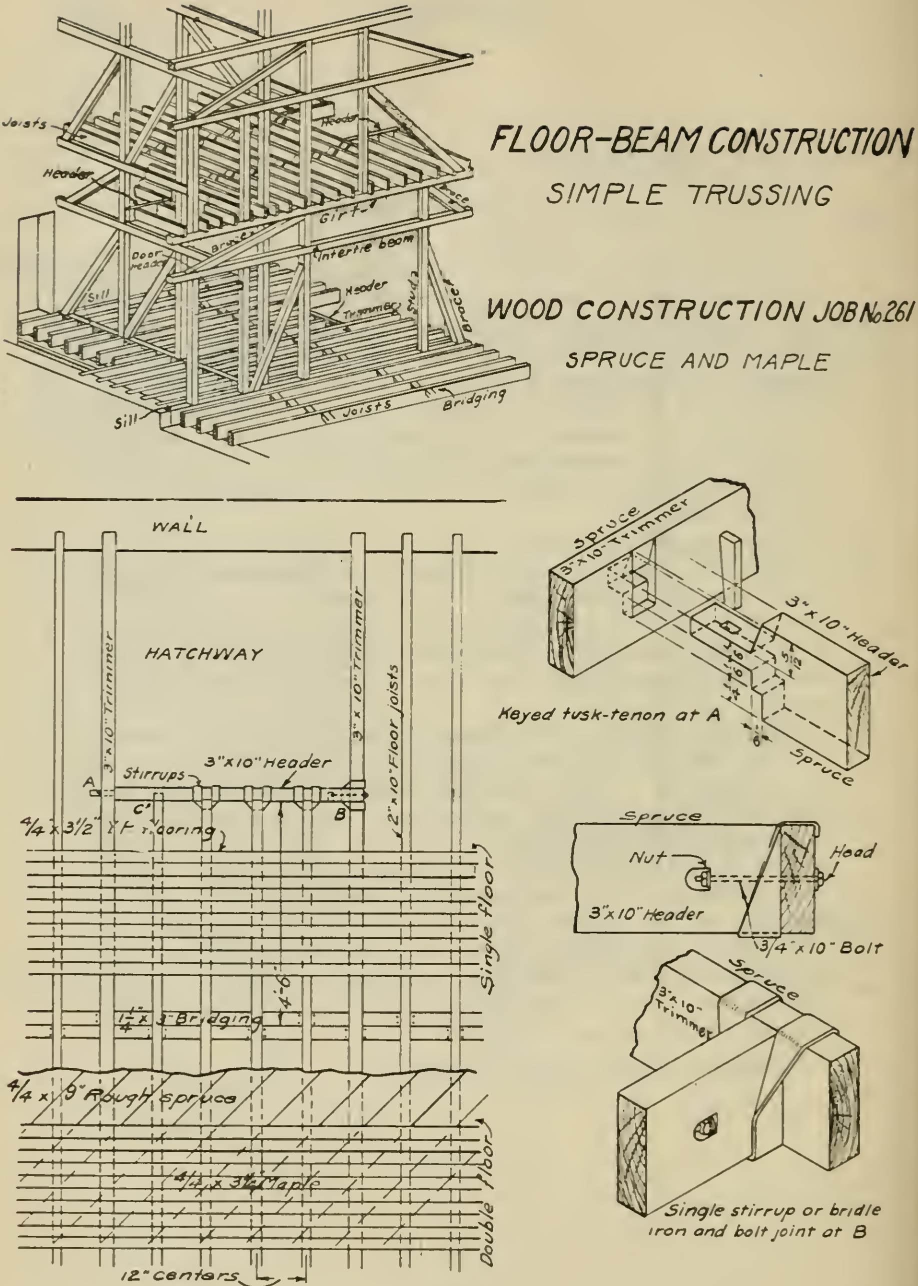
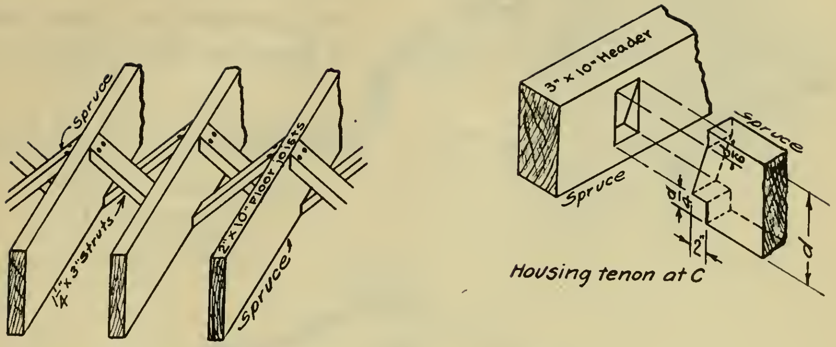

FLOOR-BEAM CONSTRUCTION
SIMPLE TRUSSING
WOOD CONSTRUCTION JOB No 261
SPRUCE AND MAPLE
Joists
Header
Header
Brace
Girt
Brace
Door header
Intertie beam
Sill
Header
Trimmer
Studs
Brace
Sill
Joists
Bridging
WALL
HATCHWAY
3"x10" Trimmer
3"x10" Trimmer
2"x10" Floor joists
Stirrups
3"x10" Header
A
B
C'
4/4 x 3 1/2" Y.P. flooring
Single floor
1 1/4" x 3" Bridging
4'-6"
4/4 x 9" Rough spruce
4/4 x 3 1/4" Maple
Double floor
12" centers
Spruce
3"x10" Trimmer
3"x10" Header
Spruce
Keyed tusk-tenon at A
Spruce
Nut
Head
3"x10" Header
3/4"x10" Bolt
Spruce
3"x10" Trimmer
Single stirrup or bridle iron and bolt joint at B

Fig. 6.



Housing tenon at C

Cross-bridging of flooring.

FIG. 6½.

Material Required.—2 pcs. ⅘ x 9 in. x 14 ft. rough spruce for double flooring, 2 pcs. 1¼ in. x 3 in. x 12 ft. rough spruce for bridging, 2 pcs. 3 in. x 10 in. x 6 ft. rough spruce for headers, 2 pcs. 3 in. x 10 in. x 14 ft. rough spruce for trimmers, 4 pcs. 2 in. x 10 in. x 10 ft. rough spruce for joists, 2 pcs. 2 in. x 10 in. x 14 ft. rough spruce for joists, 5 pcs. ⅘ x 3½ in. x 8 ft. yellow pine for single flooring, 7 pcs. ⅘ x 3¼ in. x 7 ft. maple for double flooring, 1–¾ in. x 10 in. machine bolt and washer, 3–2 in. brindle irons, 1–3 in. bridle iron, 30 8d. (2½ in.) wire nails for bridging, 30 6d. (2 in.) wire nails for Y. P. flooring, 30 6d. (2 in.) brads for maple flooring.

Work.—Setting floor joists, trimming around hatchway, jointing and use of substitutes, bridging, laying single and double floors.

Tools.—From Tool Room: 1 in. framing chisel, 1½ in. framing chisel, brace, 14/16 in. auger bit, 2 in. expansive bit, 5 ft. folding rule, carpenter's pencil, 3½ in. round mallet, 12 in. monkey wrench. From Tool Drawer: cross-cut saw, rip saw, claw hammer, T-bevel, try square.

Directions.—(0) Use given dimensions only. Do not scale drawing. (1) Mortise trimmer beam for keyed tusk-tenon shown at *A* with 1½ in. framing chisel and bore ⅞ in. hole through other trimmer at *B*. (2) Cut header beam to length and make tusk-tenon at *A* with cross-cut saw and 1½ in. framing chisel. Cut hole for key with 1 in. framing chisel. Bore ⅞ in. hole at *B* for bolt. Mortise for housing tenon at *C*. (3) Place header in position. Key and bolt to trimmers. Set bridal irons on header and place floor joists on 12 in. centers for heavy floor, or 16 in. centers for light floor. Put in bridging struts. (4) Lay and blind-nail single flooring, using matched boards. Break heading joints. (5) Lay double flooring of spruce and maple.

KING-POST TRUSS

FOR SUPPORTING LOADS OVER
A SPAN OF FROM 18 TO 30 FT.

WOOD CONSTRUCTION JOB No. 262

YELLOW PINE
(LONGLEAF)

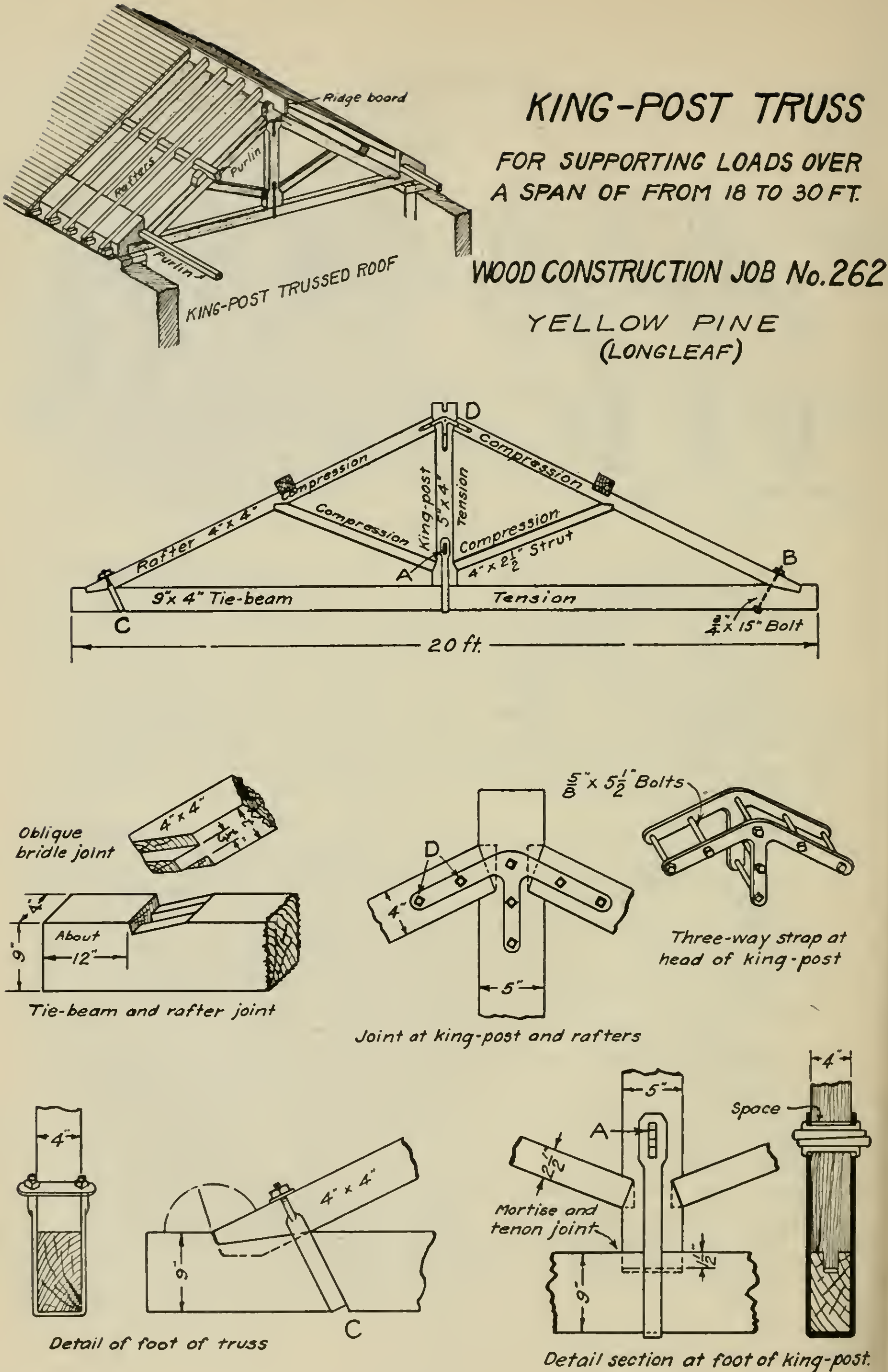


Fig. 7.

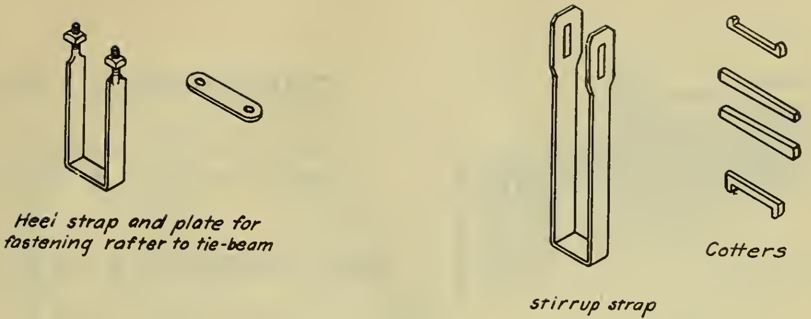


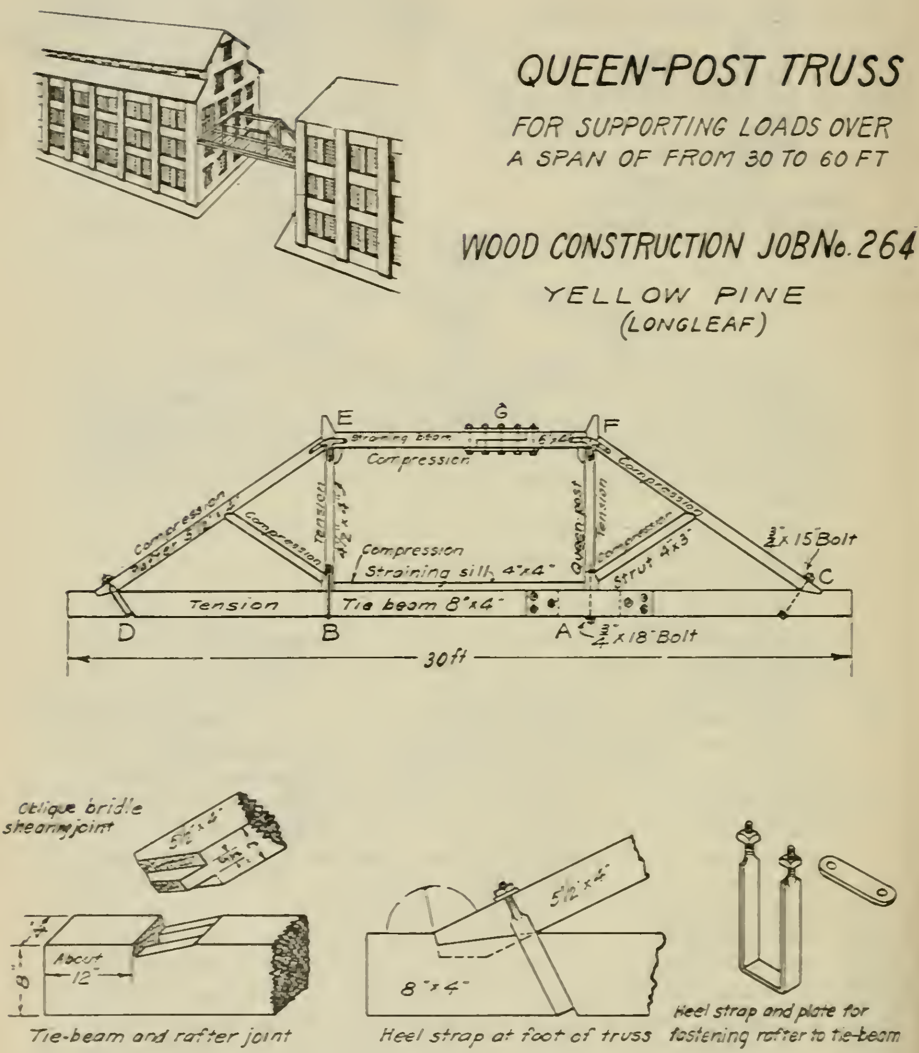
FIG. 7½.

Material Required.—1 pc. 5 in. x 4 in. x 7 ft. L.L. Y.P. D4S for king-post, 1 pc. 9 in. x 4 in. x 15 ft. L.L. Y.P. D4S for tie-beam, 2 pcs. 4 in. x 4 in. x 10 ft. L.L. Y.P. D4S for rafters, 2 pcs. 4 in. x 2½ in. x 6 ft. L.L. Y.P. D4S for sruts, 1–¾ in. x 15 in. machine bolt and washer, heel-strap and plate, stirrup strap and cotters, three-way straps and bolts.

Work.—Trussing for short spans, jointing for specific strains, calculating a shearing joint, strapping joints.

Tools.—From Tool Room: 1 in. framing chisel, 1½ in. framing chisel, ½ in. mortising chisel, 24 in. x 2 in. steel square, brace, 12/16 in. auger bit, 14/16 in. ship auger, 12 in. monkey wrench, carpenter's pencil, 3½ in. round mallet, 5 ft. folding rule. From Tool Drawer: cross-cut saw, rip saw, claw hammer, try square T-bevel.

Directions.—(0) Use given dimensions only. Do not scale drawing. (1) Mortise tie-beam for king-post with 1 in. framing chisel. (2) Tenon king-post to fit mortise in tie-beam. Place king-post in position, square with tie-beam. (3) Locate on tie-beam and king-post, positions of rafters, and mark off bevels for joints at top at foot of rafters. (4) Mortise tie-beam and king-post for rafters. Cut rafters to proper length, then bevel and tenon to fit tie-beam and king-post. Lower end of rafter should be cut so as to bisect the angle between top of tie-beam and outside of rafter. (5) Place rafters so as to get position and bevel of struts. Mortise king-post and rafters for struts. Cut struts to length and tenon. (6) Mortise king-post at *A* with ½ in. mortising chisel for stirrup-strap cotters. (7) Bore ⅞ in. hole at *B* for ¾ in. bolt. Notch in tie-beam at *C* for heel-strap. Bore ¾ in. holes at top of king-post *D* for three-way straps. (8) Place straps and bolts in position and fasten members of truss securely.

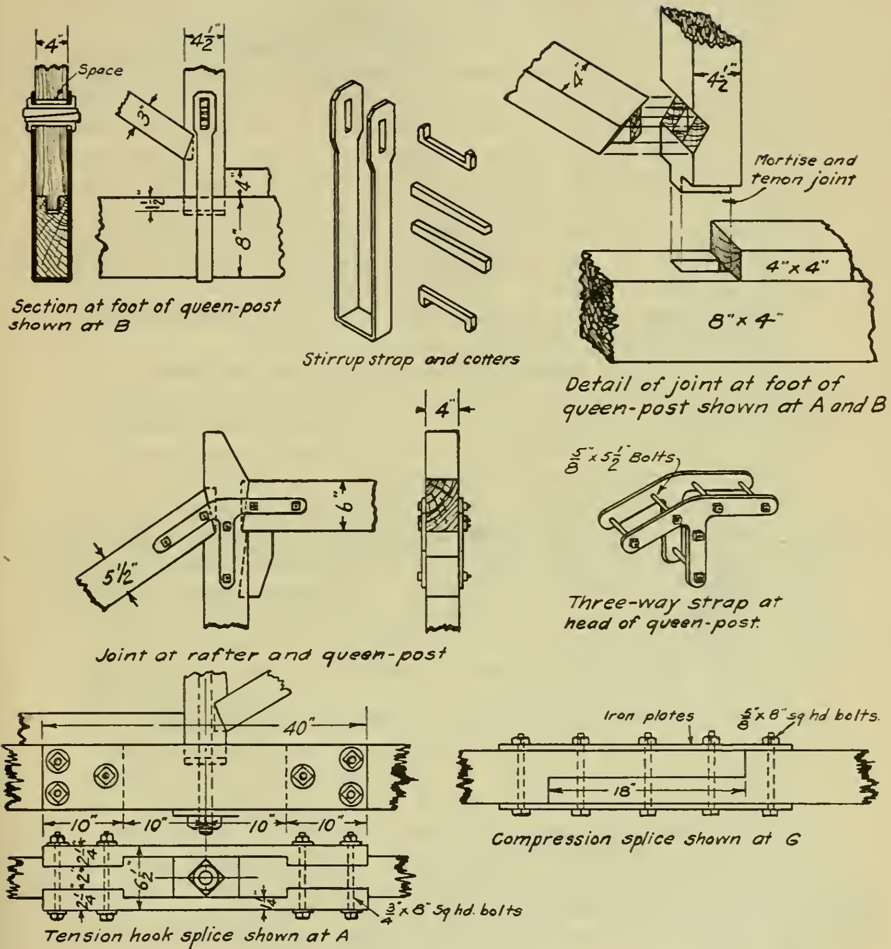


Tie-beam and rafter joint

Heel strap at foot of truss

Heel strap and plate for fastening rafter to tie-beam

FIG. 8.



Section at foot of queen-post shown at B

Stirrup strap and cotters

Detail of joint at foot of queen-post shown at A and B

Joint at rafter and queen-post

Three-way strap at head of queen-post.

Tension hook splice shown at A

Compression splice shown at G

FIG. 8½.

Material Required.—2 pcs. 5½ in. x 4 in. x 10 ft. L.L. Y.P. D4S for rafters. 1 pc. 8 in. x 4 in. x 6 ft.–6 in. L.L. Y.P. D4S for tie beam, 1 pc. 8 in. x 4 in. x 13 ft.–6 in. L.L. Y.P. D4S for tie beam, 1 pc. 6 in. x 4 in. x 7 ft. L.L. Y.P. D4S for straining beam. 1 pc. 4 in. x 4 in. x 7 ft. L.L. Y.P. D4S for straining sill. 2 pcs. 4 in. x 3 in. x 5 ft. L.L. Y.P. D4S for struts. 2 pcs. 4½ in. x 4 in. x 7 ft. L.L. Y.P. D4S for queen-post, 1–¾ in. x 15 in. Sq. hd. bolt and washers. 1–¾ in. x 18 in. Sq. hd. bolt and washers. heel strap. with plate and nuts, stirrup iron and cotters, 12–⅝ in. x 5½ in Sq. hd. bolts and nuts. 4 three-way straps. 6–¾ in. x 8 in. Sq. hd. bolts and washers, 5–⅝ in. x 8 in. Sq. hd. bolts, 2 pcs. 8 in. x 2¼ in. x 40 in. L.L. Y.P. D4S for tension hook splice 2–⅝ in. x 4 in. x 27 in. compression plates.

Work.—Trussing for long spans, splicing for heavy loads, proportioning joints for tension. compression and shearing strains.

Tools.—From Tool Drawer: cross-cut saw. rip saw. claw hammer, try square. T-bevel. From Tool Room: 1 in. framing chisel, 1½ in. framing chisel, ½ in. mortising chisel. 24 in. x 2 in. steel square, brace, 1²⁄₁₆ in. auger bit. 1⁴⁄₁₆ in. ship auger, 12 in. monkey wrench, carpenter's pencil. 3½ in. round mallet, 5 ft. folding rule.

Directions.—(0) Work to given dimensions. Do not scale drawing. (1) Make tension hook-splice joint in tie-beam at foot of queen-post *A*. (2) Mortise tie-beam for queen-posts with 1 in. framing chisel. Tenon queen-posts to fit mortises in tie-beam. (3) Make compression splice joint in straining beam *G*. Cut straining beam to length. and tenon ends. Mortise and bevel top ends of queen-posts to fit tenons of straining beam. (4) Erect queen-posts on tie-beam. Place straining beam in position. See that posts are set square. (5) Locate positions of rafters and mark off bevels for joints at tie-beam and queen-posts. (6) Mortise tie-beam and queen-posts for rafters. Then tenon rafter joints to fit tie-beam and queen-posts. (7) Place rafters so as to get position and bevel of struts. Mortise queen-posts and rafters for struts. Cut struts to length and tenon. (8) Bore ⅞ in. hole in queen-post at *A* with ship auger. and mortise out for nut. Mortise queen-post at *B* for stirrup cotters. Bore ⅞ in. hole at *C* for tie-bolt. Notch in tie-beam at *D* for heel strap. (9) Bore ¾ in. holes at top of queen-posts for three-way straps. Place straps and bolts in position. and fasten members of truss securely.

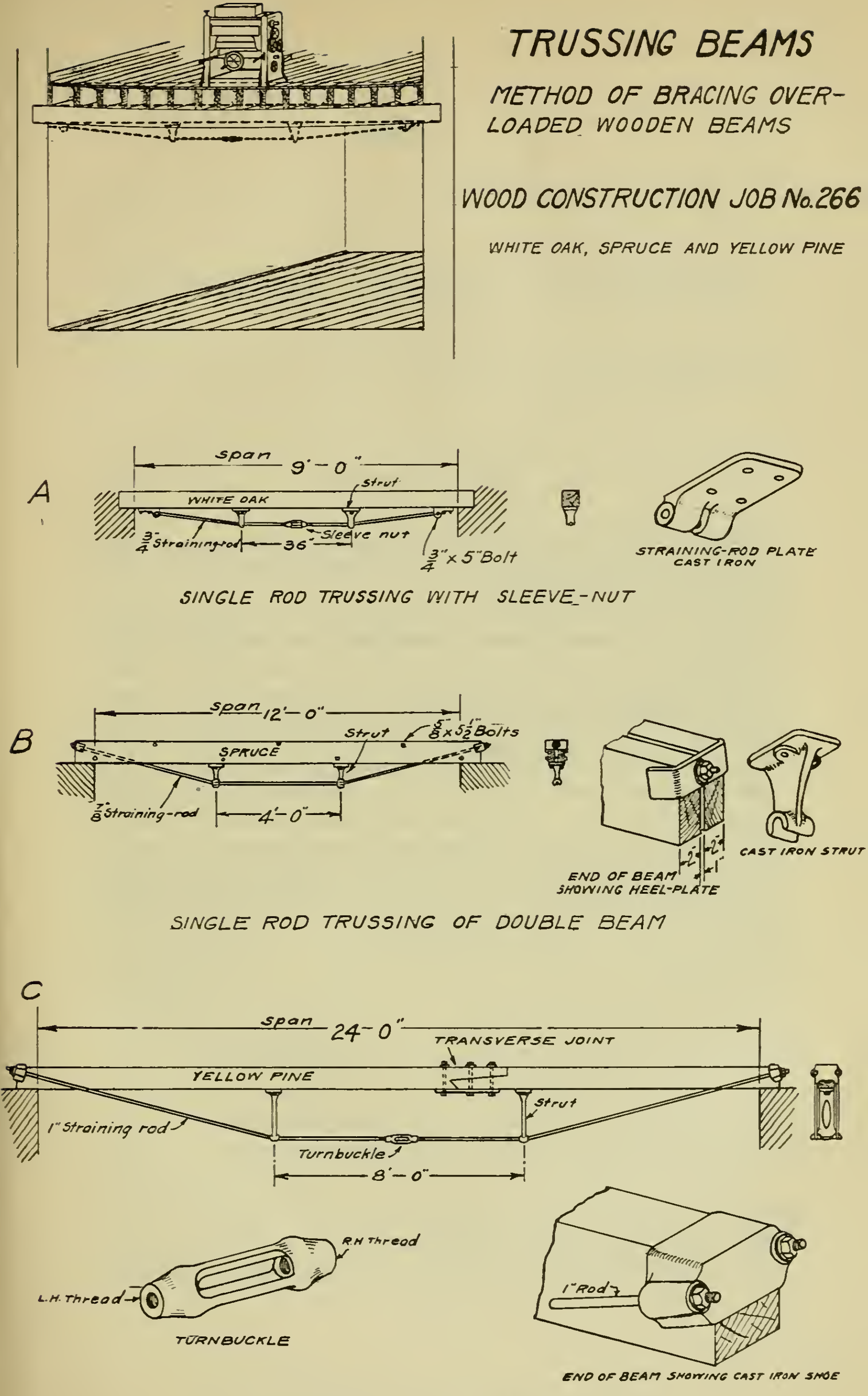


Fig. 9. Double-rod Trussing with Turnbuckle.

TRUSSING BEAMS

(Shown in Fig. 9.)

Work.—Proportioning and compounding wooden beams for trussing, splicing long beams for transverse loads, locating, fastening and use of iron struts and straining rods.

Tools.—From Tool Room: 8 in. adjustable "s" wrench, turnbuckle wrench, 1 in. open-end wrench, ¼ ton chain hoist, 200 pound weight, 5 ft. rule.

Directions.—Beam *A:* Place 200-pound load upon center of beam. Measure deflection of beam. Put plates in position and place struts at one third of span. Fasten straining rod in position. Take up load by turning sleeve-nut until there is no deflection of the beam. Beam *B:* Place load upon center of beam. Put struts and heel plates in position. Screw up nuts on ends of tie-rod until beam is straight. Beam *C:* Place load upon beam. Put shoes, struts and tie-rods in position. Screw up nuts on ends of tie-rods, so as to bring rods against struts. Then take up load on beam by screwing up turnbuckle on tie-rods. Be sure to have strains equal on both rods.

COÖRDINATING DRAFTING AND SHOPWORK.

BY F. G. HIGBIE,

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Various plans have been discussed before this society showing how the colleges and the industries may coöperate, and a number of papers have been presented describing the methods used at some institutions for coördinating college work and commercial work, but up to the immediate present not much has been said about coöperation and coördination within the college itself between courses and departments. In nearly all engineering colleges relations exist between courses and departments which are not dissimilar to the relations which exist between similar branches in practical engineering work, and it would appear that any plan which establishes this relation and makes use of it as a part of a college course is worth the attention of this society.

In the May *Bulletin* of the society Professor C. W. Park contributes an excellent article on "Coöperative Courses in English" in which he describes how the work in English is coördinated with other engineering work at the University of Cincinnati in a manner which convinces one both of the desirability and feasibility of such an arrangement, and it is the purpose of this paper to emphasize as much as it may, the idea of coördination of courses by pointing out the advantages and results of such an arrangement as they have been demonstrated in connection with the coördination of a course in machine drawing and a course in shopwork at the University of Iowa.

The purpose in undertaking this coördination was to provide the students at the university with an opportunity for following manufacturing processes from the drafting room through the pattern shop, the foundry, the forge shop, and the machine shop to the assembly floor and possibly the testing floor. Incidentally the arrangement provides the university shops with a drafting department and the drafting department with a laboratory wherein its drawings may be submitted to that ultimate test which proves the worth of its product. The actual purpose of the coördination was, however, to provide the students with a means of getting actual manufacturing experience and an opportunity to study the essential relations which exist between the various steps in manufacturing processes,—a purpose of vital importance where engineering instruction is carried on somewhat removed from actual contact with the industries.

As it now operates the plan is the result of a purely natural development,—it is not to be inferred that it is perfect or incapable of further development,—and this fact has contributed in a large measure to its success. The arrangement originated with the desire upon the part of the department of mechanical engineering and the department of drawing to make two courses supplement and emphasize each other, and since no changes of instructors or of time schedules or of courses were made necessary by the introduction of the idea, it was decided to make the experiment for the satisfaction of finding out what the results would be. Since conditions at the University of Iowa are quite similar to conditions at other institutions, so far at least as the courses concerned in this experiment are concerned, it is worth noting here that if the results of this trial coördination meet with approval the same experiment may be made and the results to be secured demonstrated under local conditions without incurring any expense whatever, or making any changes in existing courses.

There are only two factors essential to the success of such a plan of coördination, and in order of importance they are:

First, the actual desire to make the plan a success on the part of the departments concerned.

Second, an object to manufacture.

Assuming that the interest and willingness to coöperate of the departments concerned may be secured, and that the individuals within those departments actually engaged in doing the routine work involved are sincere in their efforts, there remains the necessity for securing an object to manufacture.

At first thought this must seem the easier one of the essential elements to acquire but this is not the case. There are certain fundamental requirements which an object must satisfy before it should be allowed to become a part of this coördination scheme, and not every object can meet these requirements. In the first place, an object possessing interest to the student must be selected; in the second place, to make it must be within the capacities both of the students and of the shops; thirdly, it must have in its makeup enough kinds of machine operations to afford the proper variety of shop experience; and fourthly, it must be of a character that will permit of its completion within the time allowed for the courses concerned. When these considerations are met so far as the shop is concerned the object must be examined for its adaptability as a drafting-room problem. The object selected for the experiment was a small vertical gas engine, and it has proved itself a very happy selection indeed; for, in addition to meeting all of the above stated requirements, it has aroused great interest among the students. This student interest has proved to be such an important factor in the success of such a scheme of coördination that it is well to note here that it is believed that without this great interest in the product which they are making the students would get little benefit from the plan at all. It is of vital importance, then, that a judicious selection be made of an object to manufacture.

The university shops had built one of these engines before the plan was put in operation. During the construction of this first engine, which was built from somewhat crude and hastily made drawings, it became apparent to the shop instructors that the increased interest of the students in their shopwork made the production of such an object very much worth while but that to make the engine successfully the students should have good shop drawings. At the time these conclusions were being reached in the shops similar and supplementary conclusions were being reached in the drafting room. In other words, the instructors in machine drawing felt that greater interest would be stimulated in the production of shop drawings if it were possible for the students to see those drawings actually in use later on, and that the students would acquire a greater appreciation of the worth of a drawing if they could have the opportunity to follow it through the shop. The result of these conclusions in these two departments was a conference, and following that the inauguration of the plan which is now in operation.

Although it was in the middle of the course the drafting department at once took over the job of remaking the drawings of the engine which had already been built, and thus it turned out that in the drafting room students found themselves making drawings of parts for which many of them had made the patterns. This reversal of ordinary procedure turned out to be something like the description of manufacturing processes given by a young woman who was asked to write an essay on the building of an engine. She stated that "a hole was dug in the sand which was filled with hot iron. The engine was then taken to the drawing room and drawn." It was not expected that the first set of drawings would be worth much for shop purposes and no one was disappointed in the result. They served one purpose, however, and proved the assertion so often made that a finished machine is seldom like its drawings. While these first drawings were not worth much from the point of view of the shop they did show the students who later used them of the importance of having the drawing correct, and as many of the students were obliged to use drawings in the shop which they themselves had made many of the teachings of the drafting room were forced upon their attention in a very striking manner.

The course in drafting which is a part of this plan comes in the sophomore year. Before entering this course each student is required to have had a five-hour course in elementary engineering drawing and a five-hour course in descriptive geometry; in addition to this work each student has had four hours of shopwork including woodworking, forging, molding, and elementary pattern-making. The courses in drawing and descriptive geometry are designed to train him to execute and interpret drawings within a reasonable time and while he is not considered a finished draftsman a high standard of drawing is expected and demanded of him upon the completion of these courses. The courses in shopwork teach him to make a pattern and get a usable casting from it and in this work use is made of the drawings made the year before. In this sort of shopwork the student gets an appreciation of a drawing which can be taught in no other way.

With this preparation the sophomore class begins its work in machine drawing. During the year just closed the work in this course was conducted in the following manner. Each student at the beginning of the course purchased a complete set of blue prints and photographs of the first gas engine, and the first job consisted in making a complete assembly of the engine. This problem gave each man a good working idea of how the engine assembles and of the relation of its various parts. When the assembly was completed,—and it was insisted that the assembly be made exactly according to the data on the blueprints—it became apparent that changes were necessary at several points in order to have parts fit and to get an engine which would operate properly.

At this point conferences were held between the shop men and the drafting instructors to decide upon the nature and character of these changes. Several suggestions were made which seemed feasible and it was decided to work out all of them. Accordingly the assembly drawings were changed by the students until a design was obtained which met with the approval of all concerned, and the drawings were traced. It also developed during the making of the assembly drawing that at a number of places the engine could be simplified, parts could be altered, and sizes changed to advantage. Many of these ideas came from the students themselves and others from the instructors of both departments, and it was decided to work out all ideas which seemed practical. This not only furnished added interest to the work but provided a variety of problems large enough to furnish each individual with a particular job.

Following the completion of the assembly drawing the work in detailing began. Time did not permit each student to make a complete set of details, so the work was arranged to give each student as many representative details as possible. Since all of the details were not equally hard to draw, careful planning on the instructor's part was necessary to make sure that students were worked equally. Nor was it safe to assign one detail to a man in the belief that he would turn out a usable shop drawing, so each problem had to be assigned to more than one man at least. To do this successfully presupposes a knowledge on the part of the instructor of the capabilities of the students under him, and an ability to judge the amount of time needed for any given drawing. As fast as these drawings were completed in pencil they were turned in for approval and checking, and to avoid loss of time the student took up at once his next sheet of detailing. As soon as he finished his detailing each student was given several pencil drawings of details made by other men to check, and at the same time his own details were checked by someone else. After this work was done the details were traced with the understanding that the tracing was subject to revision after final checking.

When a complete set of details were secured they were blue-printed and submitted to the department of mechanical engineering for final approval and acceptance. Some revisions were necessary owing to the fact that the drawings called for the use of certain tools not in stock in the shop, and also to some changes which developed after the drawings were started, but when these changes were made the drawings were approved and sent to the shop to supersede all former drawings.

During the time which remained after the drawings for the gas engine were made certain other problems were taken up. Among others some ideas on a mixing valve for this same engine were worked out, a gasoline pump was designed, and its connection to the engine was studied; also a design for a small machine tool was studied with the intention of developing an idea suitable for material for the class next year. While the time remaining was insufficient for a complete development of these ideas they were carried far enough to make them available for problems ready for next year's class.

At the conclusion of their work in drafting the students followed the gas engine through the machine shop. Working from castings which had already been made before they began the work in drafting, and from other rough stock the parts of the engine were finished according to the drawings and ultimately assembled. While it is not the purpose of this paper to discuss the methods used in the shops in detail it may be well to note that the work on the gas engine furnishes a large part of their practice, and exercise work is given only where this object fails to furnish the experience needed for a full knowledge of shop processes.

In the drafting room a commercial atmosphere is maintained as far as possible. Students are obliged to keep an accurate record of their time and of how it is spent, their work is judged largely upon its availability for shop use as well as upon merit, they are required to have knowledge of commercial sizes and to keep the fact in mind that cost is a controlling factor in production. During the progress of their drawing students are constantly reminded of shop operations and one of the functions of the instructor in drawing is to ascertain that as a student makes a detail of a part he is also thinking of how it will be made in the shop; by this means students rapidly come to the conclusion that even though a drawing be otherwise correct it will not be worth much until it also specifies good shop practice in the making of the part.

It may be well now to summarize briefly the results of this method of teaching and to point out the benefits to be derived from coördinating drafting with shopwork as they have been demonstrated by this experiment. From the standpoint of the drafting room the advantages are these:

1. The increased interest of the student. This interest is due not only to the natural interest in the object being drawn but also to the fact that what is being drawn is also being built.

2. The course in drawing is made practical. The student is actually a draftsman for the time being and learns what his relation to the shop should be. He also learns and appreciates why a draftsman should have knowledge of shop practice, and the importance of certain features of drawings from the shop man's point of view.

3. The students have the opportunity of watching the drawings thus made submitted to actual use in the shop. It is this opportunity which affords the student the best insight into the value of a drawing and of how it should be made.

4. The greater interest of the instructor. Knowing that the work done in the drafting room is going to live the instructor takes to his task of teaching a much greater interest than he ever could give to mere exercise work.

From the standpoint of the shop the advantages of the plan as seen by Professor B. P. Fleming, head of the department of mechanical engineering, are:

1. The greater interest of the student. This interest is due largely to the character of the object being manufactured and somewhat less to the fact that irksome exercises are generally done away with.

2. The increased effectiveness of the course. This is due to the coupling up of all the shop operations on one job; under the present arrangement a student may watch the same engine part go through all of the shop operations and under the method of teaching by exercises this is not always possible.

3. The increased efficiency of the shop teaching. As the parts of the engine become standardized shop instructors will acquire a specialized teaching experience which will add much to the effectiveness of the instruction.

4. The economy of shop operation. Having a standardized product tends to make waste less and to put the purchasing of supplies and tools on a more economical basis.

5. The fact that new work may be studied and worked up in the drafting room as a preliminary to shopwork has made it possible to expect better and more intelligent work from the students.

The most striking advantage from the standpoint of both departments consists of the effect upon the student of knowing that he is a unit in a well-organized scheme of production, and it is felt by those connected with this work that much of the increased efficiency which has resulted is attributable to this cause.

The disadvantages of this plan of instruction as they have been found thus far are not considerable. From the standpoint of the drafting room there was found a tendency to let the quality of the drawing suffer owing to the efforts which were being expended in other directions. Knowing this tendency it should not be difficult to avoid it. In the shops the only disadvantage is in reality a danger. It consists in the possibility of overlooking the fact that the shops are conducted primarily for instructional purposes. If this fact is realized there should be no difficulty in keeping the shop as a part of an educational institution instead of allowing it to develop into a manufacturing plant.

In conclusion it should be stated that, in addition to the fact that this plan of instruction possesses many advantages and no serious disadvantages, up to the present time no advantage in any other plan of instruction in either course has been found which may not be included as a part of the scheme under discussion, and it is felt by those acquainted with the results and possibilities of this arrangement that it has much to commend it.

Discussion.

Dean C. L. Cory: I want to personally express my very great appreciation of the papers which have just been presented. Of course you all well know that the Western fringe of the American continent cannot be said to be extensively developed as far as general manufacturing is concerned, but

I am sure that I would be derelict in my duty if I did not extend personally, for the portion at least of the Pacific coast which I represent at this meeting, not only my congratulations, but also real encouragement to Dean Walker, Director Benedict, Principal Williston and Professor Higbee, because, as the afternoon has progressed, I have the more clearly appreciated how you in the East and Middle West are preparing young engineers to meet the problems that are the most real as well as the most serious on the entire Pacific Coast, extending from Old Mexico to Alaska.

It was Mark Twain, I think, who was responsible for the statement that a gold mine was "a hole in the ground owned by a liar." Possibly some of us, as a result of personal experience feel the desire to extend that definition to include an "oil well" as well as a "gold mine." At the present time there are oil wells in the petroleum fields in many parts of the country, and of course the production of petroleum in California is exceedingly large. At the same time there are many gold mining properties on the Pacific coast.

I happen to know of my own knowledge some of the problems presented in the operation of some of the larger oil fields and mining properties. It is worth noting that a gold mine differs, as far as the manufactured product is concerned, from, we will say, the manufacturing plant of the General Electric Company, the Baldwin Locomotive Works or the International Harvester Company, in that with the gold mine there is never any question as to the market value of the product or the ability of the country to absorb the greatest possible output.

Therefore, as soon as the total aggregate value of a large gold producing property is approximately determined, it only becomes necessary to estimate the cost of recovering the product, namely, gold.

May I give you a few actual figures regarding some of the largest gold mining properties in Alaska, notably the famous Treadwell Mine, on Douglas Island, and other newer properties on the mainland, directly across the Gastineau Channel.

By reciting to you a few facts in reference to these properties I believe I will be able to illustrate the importance of the four papers which have just been presented.

One of these properties which has just begun effective operation has been developed by unquestionably the most eminent graduate of the Rolla School of Mines, of the University of Missouri. A body of ore, low grade, so called, approximating one hundred million tons, having an estimated average gross value of $1.50 per ton, has been blocked out. The chief engineer of that company, responsible for all power production and utilization as well as repairs to equipment, including transportation, is a young man who has been out of college about ten years. By indicating his duties you will have no difficulty in realizing the importance of the papers presented in outlining preparation of men so that they are effective and valuable assistants.

In the first place, the machine shops that are required represent an investment of not less than $200,000 annually. The amount of money expended under the chief engineer's direction in building new equipment and carrying out the necessary repairs involves an annual expenditure of not less than $100,000. During the past three years there has been spent $800,000 in the construction of two hydro-electric plants. At the present time, an additional plant of similar character, costing $1,000,000 is being built.

Ultimately, 20,000 tons of ore will be mined and milled every twenty-four hours at this mine, requiring approximately 20,000 horse power.

The kind of work Director Benedict is giving his students could not be better for the training of young men who will have charge of the machine shops and the erection of these power plants. The greatest possible economy in the mining and milling of the ore is of course necessary. The ultimate saving of one cent per ton in power and for repairs, for instance, will represent $200 per day, or approximately $75,000 per year.

Referring now to Principal Williston's paper, to see what he is doing for his students to prepare them for the greatest ultimate usefulness in such an enterprise: The mills for the recovery of gold are all steel frame buildings, of fireproof construction. with the most solid concrete foundations, not only for the building but for the machinery, as well. In addition. there are not less than 150 cottages to be built for housing the employees and their families. All this work is done under the direction of the chief engineer.

It is of course clear to all of you that the young men in your eastern institutions are receiving exactly the training necessary to make them of the greatest possible service in the operation of such an enterprise. Such industries are of course to be found all over the world, especially in South Africa and South America.

Similar illustrations might be given in connection with the petroleum industry. The magnitude of the shops and structures would, I am sure, be a surprise to many of you.

Personally, I should be glad if Director Benedict would indicate to us what disposition is made of the product of the shops at the University of Illinois. I fully appreciate that the laboratories can utilize a great deal of such equipment, but although there is little danger of the output of the shops of the University of Illinois exceeding the output of that automobile concern in Detroit which does not make the most expensive automobile, yet the production of a large number of gas engines, for instance, of a certain size and type must be somewhat objectionable.

Another matter of interest to me is the possibility of considering the shop as also utilized in making repairs rather than in the construction of new equipment. We all are aware that the cost of repair work many times seems excessive when compared to the corresponding cost involved in the manufacture of absolutely new equipment.

Finally, I wish to express my approval of the plan of giving a considerable amount of woodwork in these classes. I was much impressed with the seemingly excessive amount of carpentry work required in the shops connected with the larger gold mines in Alaska. While the wooden parts of certain kinds of equipment have a very short life, yet no other material seems to fill the requirements. Ability to thoroughly understand how to do such wood work is therefore, as I have seen it, of quite as much importance as the corresponding ability to turn out finished machines made in the two working machine shops.

Professor W. S. Franklin: The teaching of economics and all such things which involve complicated human affairs seems to me to be the most difficult teaching in the world. I wish that every teacher of mathematics and elementary science could fully appreciate this fact, so that we would be a little more charitable toward the teachers of these difficult subjects when they do not accomplish as much as they would like, or we would like them to; and be willing to take less credit to ourselves for the tremendously big things some of us think we are doing. I know teachers of long experience in mathematics who, knowing only of their own work and the number of men who fail in it, think they are doing the most remarkable teaching in the United States of America. I know of young teachers of the mathematical sciences who are falling into this grave error. If you would put them up against the teaching economics or shop administration or any of the really difficult things they could not earn their salt.

I am tremendously interested in the kind of teaching which is most closely related to the realities of engineering and industrial life, and I must say that in listening to Dean Walker's paper describing the work at Kansas, I have for the first time been encouraged to think that perhaps the work which is being done at the University of Cincinnati is not the only hope of technical education in the United States!

Let me say it again, for a number of years I have been at the point of thinking that the kind of work which is being done at the University of Cincinnati is the only way to accomplish anything worth while along these difficult lines; and I have for a number of years believed that the greatest educational problems of our time is the problem of how to make use of the industrial and commercial establishments as schools, to the extent that they are schools. I am very much pleased indeed to listen to these papers because they constitute as it seems to me, a helpful discussion of the most difficult kind of teaching.

Dean P. F. Walker: I want to say that I am very much interested to see the line of development carried out in the shops at the University of Illinois. We, at Kansas, are on the same problem and I enjoy very much seeing somewhat in detail, so far as the lantern can show it, the character of the instructional work which is being done there.

I omitted to read a portion of my paper which shows how the work which I was outlining is tied to our shop practice. We are endeavoring to bring this point out, that the boy who is engaged in the shop in practical work must be made to think and study production, and that shop courses must become, not merely opportunities for putting in time with the development of a little manipulative skill, but courses in which boys shall actually learn something of modern construction methods. There are various ways of bringing it out and that which has been developed at Kansas is, as I see it, unquestionably successful. There may be other ways just as good.

I do believe that, as Professor Franklin says, we are up against a very difficult problem; that as we meet the conditions of the industrial world at the present time, we, in the schools, must get under the proposition and develop a line of work that is fitted in each case to the particular location, to the particular environment, and to the line of work. We must give men the training which will give them a knowledge and real understanding of the proper methods.

Professor W. J. Risley: I do not rise to defend the mathematician. I think the shop work has opened his eyes to the same point to which many other things open his eyes. The very fact that Illinois has developed this scheme shows that the old plan was not right. The credit must go to the institution which sees that it must make progress, which will study its relation to the job in hand, whether in mathematics or in shop work, or in plumbing or coöperative engineering work. The University of Cincinnati has never claimed, I think, that it has the only panacea for the difficulty. I find them to be most consistently modest and properly so. The man who does something along that line is bound to be a modest man. These gentlemen have indicated a fundamental problem, which is the orientation of the student's mind to the job in hand, and you can scheme until you are blue in the face, you can systematize all day, but if you do not get that into the head of the student, nothing of value will be accomplished. If Benedict's system ends with Benedict, it is no good; and there is a man's job to get that under the skull of the students.

We certainly have some work being done by our friend Williston. I have often wondered as new institutions have started, whether they had any justification for their existence. I have heard three or four papers by Principal Williston and I know a little about Wentworth, and I am more and more convinced that he has justification for continuing his work.

There was one hint in Professor Benedict's paper that I did not like. I meant to ask him to see if I was right in understanding it as I did. There is a difference in educational and commercial treatment. I know but little about shop work but I know this much: In the commercial shop you teach a man how to do a certain thing and then you teach him how to do it over and over again. That is entirely wrong from the educational point of view. The University of Cincinnati would be fundamentally wrong, in my judgment, if it put a man to work at a machine and kept him there for five years, turning out the same part thousands of times. I heard one remark which led me to believe that when a fellow was found to be good at one job, he was kept at it. I hope this is not emphasized. If it is not wise, of course, a man like Director Benedict would not carry it on.

Certainly we are on the right path. I think Professor Franklin is right in many of the things he insists on bringing up. and I think we should admire a man with the nerve to bring up problems as he does. I do not belong to any society which has the number of free lance thinkers this Society has, who do not think in a rut. but try constantly to keep out of the rut. As one of the few mathematicians or mathematics teachers who attend these meetings, I want to express appreciation of this Society's work.

Dean C. R. Richards: I should like to answer Professor Risley. He is entirely mistaken as to the character of the work done at Illinois. We do not put a man to work at one job and keep him there if he shows skill at that particular work. The boy may do ten times the amount of work he formerly did with the methods we give him. In the long run, the amount of time devoted to any one job is perhaps less than in the older days when manual training methods prevailed. I wish I might take an hour to discuss this method in which I have such a keen interest. I do want to emphasize one thing, however, which has been keynoted in our particular development. It is my belief that you can not teach the principles of management by lectures. and any attempt to that end will lead, in my judgment, to results which are not satisfactory. I want you to understand that our shops are laboratories and not shops in the accepted sense. They look like shops but we are running them as laboratories. These manufacturing methods are laboratory experiments in production, and we are attempting to use the best methods to develop this ideal. In addition we try to make the shops laboratories for the study of materials. To the mechanical engineer, the properties of a material as affected by shop processes are of as much or even greater importance than the strength of the material. Yet I think we have given small consideration to these problems, up to the present time.

Finally, I think we have realized that it is possible to give the student some idea of the principles of management, and we believe at Illinois that it can best be done by actually having him do the thing. If the student makes a study with a watch, he knows what a time study is. He knows what a fixture is for if he uses it. He is constantly comparing modern with old methods. A description of our processes before the American Foundrymen's Association led to one of our best men being taken as manager of a large foundry in the East.

Principal A. L. Williston: I cannot let that remark by. I am afraid my friend Dean Richards misunderstood completely what I said. I said there were two elements common to the engineer and the architect, but the third element completely upset the comparison. There is all the difference in the world between the functions of three and two variables.

One other thing I intended to say in answer to another speaker, and that is, regarding the human element in these problems. I think perhaps none of us emphasized that quite as much as we all try to practice it. Nowadays, human engineering becomes a tremendously important factor, and there are lots of things you must teach young men, which they will be called to do in human engineering which were not necessary some time ago. We must teach them how to give orders and how to give orders which will be carried out by somebody they have never seen. While I did not emphasize it, and Director Benedict did, all the way through the work these boys are working under foremen, subforemen and superintendents with the work definitely laid out for them. Positions are located from time to time; records, cost studies and all that sort of thing is done. They are receiving instructions as to how to be superintendents and foremen and how to hold down the job of material director and other jobs of that sort. The interesting thing about it all is that by introducing this training function in addition to the others, the boys carry very heavy schedules without fatigue or the kinds of resistance in the student body with which we are all familiar. I feel confident that these boys can carry forty hours a week in the school quite as happily and as comfortably as the boys I have had in other divisions could carry 23 or 24 hours a week.

Director B. W. Benedict: Dean Cory has asked what becomes of our finished product. At present the principal product of the shop laboratories is a two cylinder, eight-horsepower marine type gas engine. These are largely purchased by students for use on the farm or in motor boats. The selling price is very moderate ($75.00) and as materials and construction are first class the engines sell themselves without any effort on our part. We would not get uneasy if the engines failed to sell as our main problem is manufacturing—while selling is incidental only. At the same time we like to see the output taken care of especially by the boys who are responsible for it. We do not anticipate any difficulty in disposing of our product regardless of its volume. If sales lag behind production we will undertake a selling campaign.

EFFICIENCY IN COLLEGE ADMINISTRATION.

BY S. B. McCORMICK,
Chancellor, University of Pittsburgh.

Efficiency in college administration is the same thing as efficiency anywhere else, except perhaps in the relative importance of it. Efficiency anywhere is desirable. It is not equally essential in all organizations or in every part of any particular organization. Efficiency is the doing of what a thing is expected to do. A watch is efficient when it keeps time. It may cost one dollar or one thousand dollars; but as a timekeeper one is as efficient as the other if it does the work. The efficiency of a steel plant is the turning out of its expected product—the right quality, in the right period of time, and with the right cost of production. The efficiency of a man is a more complicated problem. It depends upon a very considerable number of considerations. If the man sharpens needle points, and does nothing else except eat and sleep, the problem is simplified. His efficiency can be calculated as quickly and as readily as that of any other machine. Obviously, the efficiency of a man, however, involves not what he does at any particular moment, nor what may be his chief employment, but what he is himself and what he is intended to be and to do in the entire circle of his activity and relationship. His total efficiency is measured by the degree in which he accomplishes in the world what he was intended to accomplish, this depending upon the measure in which he has become the kind of person he was intended to become.

There are, therefore, in the world all kinds of efficiencies, all manner of degrees in efficiency, and all degrees of value in efficiency as well. To measure efficiency in college administration one must determine the function of administration in carrying out the whole purpose of the institution, and in addition one must measure the function of the institution as it stands related to other institutions and activities in the world of which the college is a part. To do this is as difficult and complicated a process as would be the process of measuring with any accuracy the efficiency of a human person. We may assume the importance of efficiency in college administration, and if in the development of the discussion it would appear that this importance is relatively large, it will occasion no surprise.

Let us, therefore, refer to two or three considerations which should be kept in mind. In the first place, the high function of the college itself. We may take for granted in this connection that the word "college" is a generic rather than a special term, and that it includes colleges, universities, technical schools, and in general higher institutions of learning. The function of such institutions is a remarkably complex affair. It has to do with character, with culture, with conduct, with scholarship, with research, with technical skill, with professional attainments, with the solution of every kind and variety of problem touching the social, economic, political, industrial, health and other interests of a great nation. If it is important that an industrial or transportation or governmental corporation should be efficient, so as to render effectively the service it is designed to render, it is perhaps much more important that an institution of learning should be efficient, touching as it does every possible phase, interest, motive and activity of community, state and nation.

Again, it is equally clear that the importance of efficiency varies according to the point of application in the order of relationship. Efficiency in the part of an organization which touches every other part is clearly more vital than efficiency in the part of it which is relatively unrelated. Efficiency in the president is more important than efficiency in an humble employee. It is just as necessary that the watchman at a grade crossing of a railroad shall do his work properly, which is to warn the people from danger, as it is that the train dispatcher shall do his work properly; but the consequences to the corporation are evidently of more vital concern in the case of the dispatcher than in the case of the watchman. It is important that the bottle machine which is expected to turn out a product of two thousand bottles an hour shall do its work. It is more important that the administration of the glass company, which has in charge manufacturing and selling and paying dividends on stock, shall do its work. Efficiency in both cases is important, but varies in its consequences according to the place where it is applied, as touching the related parts of the entire organization.

Still further, it may be possible to conceive efficiency as being so essential, a matter of first importance, as to put it out of its proper place and cause maladjustment everywhere, with consequent disaster. Along with efficiency must be kept in mind other things equally important, and yet not necessarily incorporated in that particular concept. German efficiency is a word to conjure with. It is as remarkable in the idea it conveys as it is in the actual fact it represents. Germany has as many and as lofty ideals as has any other people under the sun. It has had as many scholars, philosophers, poets, scientists, musicians, statesmen, military leaders and other great men in all departments of life as any other great nation has produced. We may perhaps be within the limits of moderate statement if we say that Germany has had more of these than any other nation in modern times. I wonder whether we might be equally within the limit of reasonable statement if we should say that so completely has the idea of efficiency taken possession of the German people that it may stand as the one great, overmastering idea and ideal of the nation. It is no exaggeration to say that German officialdom knows more of England and of France and of Russia than any man or perhaps any set of men in these countries know of themselves. Yet, once more, is it not a very moderate assertion that Germany has become so absorbed in what efficiency means as to forget that it does not mean everything, with the result that Germany understands less about other nations than perhaps would be true of any other nation in the world, however inadequately informed about others that nation might be? What matters it if in the pursuit of efficiency one forgets the high purpose for which efficiency is sought, and thus fails in making efficiency itself do the thing it is intended to do?

With these reflections, we turn to the discussion of efficiency in the administration of an institution of learning. It already appears, from the relation the administration bears to every part of the institution and from the relation the institution bears to every interest in the nation, that we are speaking of a place where efficiency is most vitally essential, and where the lack of it is most disastrous. If the administration plans wisely and executes effectively, it touches every part of the entire organization, and it therefore does the thing it is intended to do. If the administration does not plan wisely or does not plan at all, and if it executes carelessly, in a slovenly manner, indifferently, then the institution does not do the thing it is intended to do. What the head of an institution of learning is, that also is the institution itself, down to the laboratory assistant who takes charge of the apparatus, or the janitor who dusts the chairs and washes the windows. If the head is careless, his assistants will be careless, the office will be careless, the professors will be careless, and the institution will be slipshod in every part of it. I do not mean to say that his bad example will change for the worse every man connected with the institution: but I do mean to say that it will lower the esprit de corps of the whole organization and lessen the efficiency of its work, and give to the world a less valuable output than it should.

Take for instance the matter of promptness. Here the head comes in touch with an undesirable trait which belongs not to one set of persons only, but universally to humanity itself. *Manana* is not a word belonging to the Spanish people alone, but a thing which belongs in some measure to every human person. It is easier to be late than to be on time. It is easier to put a thing off till tomorrow than to do it today. It is not better, however, to yield to this human fault. The president not only meets this trait in those associated with him, but he actually meets with the argument on the part of some of them that, if for instance, at an appointed hour the audience is not assembled, it is better to wait for it than to begin on time. If any argument makes the writer see red, it is this argument. It is not only better to begin on time, whether the audience is assembled or not, but it is necessary, if procrastination is not to touch every part of the institution and affect for the worse the kind of work which is done throughout the whole of it. To begin a stated exercise one minute late is to commit a fault. To fail by one minute to keep an appointment is to do a wrong. It is not simply the theft of the minute from the other man or the other thousand people who may be assembled for the particular purpose, but it is to send throughout the entire establishment—the office, the classroom, the student body—a certain idea which is bad, namely, that a minute does not matter, and that it is of relatively little importance whether or not people are keyed up to the tension which is essential to achievement. If promptness has a place in the world, it has a place in the institution which is preparing men to live and to work in the world. If promptness has a place in the institution which is doing this thing, it has a supreme place in the administration of the institution, which sets the standard for every part of it. Promptness in its application to any other part of the college, in its dealings with the business world, in the payment of its accounts, in every place where this quality finds its use, is equally urgent and essential.

The second essential of efficient administration is system. A good system is of course best. Any system at all, properly administered, is better than no system at all. The business affairs of a college are as vital to its success as the business affairs of any other kind of establishment. Efficient instruction is scarcely conceivable in an institution whose business side is inefficient. The recognition of the value of business ideas, business methods, business accuracy, business promptitude, business habits, is altogether essential if the institution is to touch helpfully the commercial, philanthropic and other agencies and activities in the community.

Men absorbed in the business of education sometimes forget this fact, and overlook the outstanding consideration that an institution of learning, to accomplish its end, must be as nearly as possible a model in everything wherein it comes into contact with its immediate environment. Otherwise, it forfeits its right to the confidence of the people, and in the measure in which this happens it loses its opportunity, not only to extend and multiply its usefulness, but even to accomplish the purpose of its own existence. Loose business methods not only have a tendency to communicate themselves to every part of the institution, but unfortunately, like noxious weeds, tend to extend out into the community itself. Business men, if they give thought to the matter at all, hesitate to entrust their sons to the guidance of an institution which fails to teach its students habits essential to success in actual life. A business system, therefore, properly operated, is a fundamental condition of administrative efficiency.

If this is true in this general sense, it is still more emphatically true regarding its own activities. The very fact that the college, relatively the most simple in organization of all higher institutions, has vastly enlarged its financial operations and increased the complexity of its institutional life, compels system today where once it was relatively unimportant. In the more complex organization of the university, with its congeries of schools and its immensely increased number of relationships, this compulsion is a hundred-fold stronger. When, something more than thirty years ago, the writer was admitted to the practice of law, the lawyer who systematically kept books of account was the exception rather than the rule. Today the same man would invite quick financial disaster if he did not conduct the business side of his profession with the same exactness with which the merchant conducts his business. Precisely the same thing is true of the college. Only as every financial item and every other fact of importance has its proper place and record is it possible that the institution shall make such exhibit of its affairs as to enable the proper officers to know what it is doing.

One reason for this is the present-day necessity of exhibiting clearly and comprehensively the financial condition of the college. Publicity in its business affairs is as much a requirement as in the case of a bank or other corporation. The sunlight must stream through every part of the college management in order that its health shall be maintained at par.

Another reason for system is in order that the management may quickly and accurately ascertain the place for retrenchment and the place for enlargement. Whatever income the institution has, whether from private endowment or from state appropriation, must be economically and effectively administered. Not a single dollar can rightfully be diverted from the place where it ought to do its work to another place where it will do only half its work. Not simply because the funds expended are trust funds, therefore peculiarly sacred, but because they are limited in amount and must do their full work. System is essential to this effective administration.

Still again, in the seeking of larger funds, from whatever source—a necessity resting upon practically every institution and a necessity which must be met if the institution is efficient—there must be the kind of confidence which will attract the gifts of benevolent men. Looseness, carelessness, and extravagance instantly and rightly forfeit such confidence and necessarily lessen the flow of the life-preserving stream. Self-preservation, therefore, demands conscientious, efficient business management on the part of the college and university.

I need not add another consideration, namely, that if the administration is ever tempted to looseness and inaccuracy, inevitably the honesty of the officials themselves is endangered. Only by keying up the business management to the highest possible efficiency, compelling the most rigid inquiry and investigation into every part of the machinery, will the well-being and the honest service of those who are entrusted with the management of the institution be guaranteed. The loss or misuse of trust funds, thereby impairing endowment, by which inevitably the efficiency of the institution is greatly injured, can be prevented only by the adoption of a system of administration and operating it with unceasing and unsparing vigilance.

Once again, the head of the institution will largely determine this whole phase of administration. He cannot keep the books. He will not administer the business side of the college. He will not invest the endowments. He will not pay the bills. He will not make the purchases for the institution. But upon him, his fidelity, faithfulness, promptness, system, and the qualities of mind which affect the manner of doing things, will depend the system or lack of it in the institution.

The writer has no thought here of doing more than to call attention to this as an essential fact. It is the business of the institution itself to get some person to put into operation a system which will be satisfactory. It must include accounts, records, purchases, grounds, buildings, correspondence, and all the other things which here belong. I may be permitted to refer to the matter of correspondence, relatively perhaps not the most important of them. In my early professional life, if permitted a reference to my own practice, I formed the habit, from which I have tried not to depart, of answering each letter on the day of its being received, unless, the information not being immediately at hand, it could certainly be procured the next day. If it was likely that longer delay would ensue, the letter was acknowledged, with a promise of fuller answer later on. Efficiency in administration requires that there shall be centralization in correspondence, with large authority and with consequent responsibility.

I may also perhaps refer to the matter of records. This department of the college and university administration is perhaps for the most part assigned to the registrar. We are all familiar, however, with the very greatly increased burden of work falling upon that officer, and in the interest of the larger service the registrar's department ought to be made a distinct bureau of the general administration. It is no longer enough simply to register students, see to it that their dues are paid, and that their records are properly entered and preserved. The registrar's office has really become in these modern days a bureau of vital statistics. Here should be found the educational record of the student before he enters, together with such other personal data as may be important; a record of his work while a student; and a record of the man after he leaves the institution, sufficiently complete to enable the office at once to find him and to give such information concerning him as may from time to time be requested. This record should be so full and complete as to provide any information which may be asked about individual students, and also about the student body as a whole. The statistics should be in such form as to permit careful study of them with a view of determining lines of policy, and adopting methods of procedure which promise larger efficiency and increased usefulness on the part of the institution.

Another set of records altogether distinct from those connected with students and alumni, has reference to another side of college administration. I refer to the record of names—first, of those persons who may in any wise be interested as future patrons or future benefactors of the college or university. This should be under the charge of a person assigned to that particular duty, and should have such clerks, files and stenographic help as may be necessary.

Still another kind of record is that which concerns the relation of the institution to other institutions of a like kind or to secondary schools. This is a most important and essential department, and should have suitable provision made for it. This should include such extension work as the institution may do in connection with other schools, clubs, and organizations of all kinds.

Still again, a record should be kept of the social activities of the institution, not only that they may be put under proper supervision and control, but that there should be a sort of bureau to avoid conflicts, and otherwise to make this department of college life as serviceable as it can be made. This bureau should include not only social, but athletic and all other events which touch the activities of the student.

It is not intended that this suggestion as to records should cover all phases of the subject. I have named enough of them only to show that a department of records is an exceedingly important one, and that the demands upon it are constantly enlarging.

Still another essential to administrative efficiency is the installing of the proper organization whereby the president and his associates may keep in touch continually with the men who are carrying on the work of instruction and who are immediately responsible for the formation of right habits on the part of the students themselves. A teacher who is careless as to when he meets his classes or whether he meets them at all should engage in some other occupation, wherein his bad habit will affect himself alone. Any educational institution has one supreme purpose, namely, the training of the youth entrusted to it so that they will later efficiently serve society and the state. It is idle to imagine that educators are so distinctly a select class of men that they will instinctively do their duty and always realize the far-reaching consequences of relatively slight failure in duty. No living person so vitally affects character as does the teacher. Young people imitate their instructors, especially when they learn to love them. They are quite likely to develop in themselves the qualities they admire in their teacher. This is a truism. It is a universal experience. From the head of an institution into every part of his organization should extend a direct influence which will guarantee, so far as it is possible, highest fidelity, constant watchfulness and thorough conscientiousness on the part of the men who are engaged in the direct work of instruction.

This fact is especially true in America, and peculiarly true in this period in our national history. America is in process. Her institutions, whose foundations are strongly laid, are yet not complete. The history of America is mostly unwritten. We are only in the beginnings of our national life. Great populations, gathered from every part of the world, are to be welded into an American citizenship. The high ideals of the land are to be perfected and made to control the behavior and form the characters of this great people. The mission of

America is not to herself, but to the nations of the world. Her influence upon other peoples, whose opportunities are fewer and whose incentives to achievement are not equal to ours, is dependent upon the progress made by our citizenship. Here is the great and perhaps the final experiment of democracy. Upon the triumph of this democracy will depend not only the well-being of the entire world, but the higher progress and perfecting of civilization itself. It is obvious, therefore, that if America is to fulfill in large measure its duty and accomplish its obvious mission, it can do it only as the colleges and universities pour out into the life of the nation that kind of product which will be effective. It can do it only as the administration itself is efficient and keeps in constant touch with and inspires to the most loyal and conscientious endeavor every part of the institution itself.

It seems almost superfluous to add that unless there is coöperation, hearty, spontaneous and genuine, on the part of administration, faculty and trustees, there can be no real executive efficiency, however thoroughly organized the administration may be and however wisely system may be operated. The test of efficiency is the measure in which this coöperation is secured. The things referred to in this article will help tremendously. Like everything else, however, the essential thing is the spirit which gives life. This spirit, proceding from the head, must touch every member, and weld the whole body into a single united, effective organism with one mind, one heart, one purpose, so that, each member doing his part, the whole may attain to the highest degree of real effectiveness and genuine efficiency.

THE VALUE OF FINAL EXAMINATIONS.

By E. D. WALKER,

Professor of Hydraulic and Sanitary Engineering, Pennsylvania State College.

In a subject of such a nature that frequent recitations are possible an instructor can usually form a satisfactory estimate of the ability of his students without further tests.

The principal advantage of the final examination is its value as a means of education, since the student, in making a proper preparation for it, receives a training which is in itself most valuable. The student usually gains in this way a conception of the subject as a whole and frequently sees for the first time the relation of the parts which have formed the daily assignments or which have been considered in partial reviews. This, of course, is not true of all but statements made by the better grade of students lead the writer to believe that these men gain a better knowledge of the subject by preparing for the examination.

The writer believes that instruction in methods of preparing for examinations is a proper part of the teacher's work and he makes it a point to give such instruction to the students in his classes. After the work of the term has been completed in a given subject, if the text-book has a good table of contents which lists the titles or subtitles of the various sections, the writer directs the attention of the class to this table pointing out the more important divisions of the work and suggesting the use of the headings as a means of testing their knowledge of the subject. If the title of a given section suggests to the student a reasonably complete idea of the particular topic treated, he is advised to turn to the section in question and verify his concept. If any title fails to suggest the substance of the section, then that topic should be noted for further study. If the book lacks a suitable table of contents, then the class should be instructed how to make a proper syllabus.

The writer also gives the student some instruction in what might be termed "mental hygiene" warning them against studying all hours of the night preceding an examination and advising that their preparation be completed sufficiently early to leave time for amusements of a nature that will enable them to relax mentally and to secure proper sleep. While many disregard the advice, some follow it with apparent profit.

Engineers are usually obliged to take examinations in one form or another throughout their professional careers. The first and most obvious instance to present itself is that many national, state, and municipal positions are today filled by competitive examination. The writer has learned through friends who have had experience in teaching in institutions where final examinations are not given, that graduates of such institutions have usually shown that they were handicapped in such competitions.

Civil service examinations, however, are not the only ones that the engineer is called upon to take. Frequently the candidate for a position is given a more or less thorough examination in the form of an interview with his prospective employer and the ability to marshal facts and to give clear and logical answers to questions as to his knowledge and experience in a particular field frequently secures the position sought. Another candidate with more technical ability may fail because of his lack of such mental self-control during the "examination."

The engineer who is called upon to appear as an expert witness is certain to be subjected to a searching examination by the attorney for the other side as to his knowledge of the branch of engineering concerned and he finds it necessary to make preparation by a systematic review of the points involved and of any related subjects. Here again training in preparation for college examinations is of value and tends to breed a feeling of confidence which promotes calmness under a grilling cross-examination.

The writer appreciates that he has not presented anything new but he has endeavored to outline what seem to him some of the leading points of the subject with the hope of promoting a discussion which shall call forth ideas from others that will benefit all of us engaged in the profession of engineering education.

SOME IMPORTANT QUESTIONS IN ENGINEERING EDUCATION.

BY J. A. L. WADDELL,

Consulting Engineer.

The subject of this address was of my own selection. As, perhaps, some of you already know, the said address was not solicited by the Secretary of the Society, but was volunteered; and, consequently some of you may deem it to be in the nature of an intrusion, for on more than one occasion I have heard the remark, "what do practicing engineers know about technical education?" For fear that such a thought may exist in any of your minds, I shall begin by tendering to this meeting of distinguished technical educators a sincere apology for such intrusion. In extenuation permit me to offer you the following excuses for my apparent effrontery:

First. I once had the honor of being a member of your honorable band, for during the first eleven years of my professional career I spent six in the teaching of engineering; and, in consequence, ever since then I have taken the deepest interest in all important matters relating to engineering education, and have at various times both written and spoken upon the subject.

Second. As during the last three decades I have employed a great number of young engineers, most of them being graduates from the leading technical schools and universities, I have been able to note the shortcomings in their education, especially as, in many cases, I have taken a deep personal interest in their professional development and advancement.

Third. During the many years of my practice I have lectured to the engineering students in a large number of the leading schools and universities in all parts of the United States, as well as in Canada, and have thus become intimately acquainted with the work of their engineering professors; for when thus lecturing I invariably hold long and interesting conversations with various members of the faculty, and mainly upon the subject of technical education.

Fourth. Moreover, it is by no means a bad thing for professors of engineering to hear directly from some of those who have been largely utilizing the product of their labors.

Of late years there have been great and wonderful advances made in engineering construction and in the science of design; and you instructors must find it difficult to keep technical education abreast of the practice. Your greatest handicap in so doing is, undoubtedly, lack of time. For thirty years I have been preaching upon the necessity for five-year courses in the engineering schools; and today that necessity is a fact which cannot well be disputed. When I was a student at Rensselaer some forty or more years ago, we were worked very hard in order to learn in four years most of what was then known of civil engineering; and as I look back upon it now the amount of that knowledge appears pitiably small. How then is it possible today in a like period of time for a student to obtain even an elementary comprehension of the grand science of modern engineering? Even five years are not enough for the purely technical instruction that should be given to engineering students in the higher institutions of learning, to say nothing of the time required for cultural courses that are essential to any fairly complete engineering education. The failure of American technical schools to lengthen the time of their curricula has been to me a source of both surprise and disappointment; for I feel that our grand profession—the profession of progress—cannot advance as it should unless its members are more thoroughly trained than, as a rule, they are at the present time. It is true that certain universities claim to give five- and even six-year courses in engineering; but in nearly every case the course cannot truly be said to be of such length. Those few institutions that have attempted to make the five-year course in engineering obligatory have received much discouragement; and some of them are considering the advisability of returning to their four-year curricula. This is a great pity; and it is to be hoped that at least one or two of them will have the courage to persevere and eventually to succeed in setting the pace for the other less progressive schools to follow. I am informed that certain institutions which claim to offer six-year engineering courses give only cultural studies during the first two years. This is a mistake; for the young man who starts out to learn engineering should begin his technical studies at once; and the cultural instruction he receives should be sandwiched in during the entire extent of the course.

When I claim that modern engineering cannot be properly taught in four years of nine working months each, I realize thoroughly what I am stating; because I speak from experience gained in both teaching and practice. All engineering courses, as is now customary in a number of the leading technical schools and universities, should be lengthened to eleven months per annum by giving field and shop instruction during the summer. The change in the character of the work will generally be found more beneficial to the student, both physically and mentally, than idling through the summer days. Nothing is worse for a young man than idleness. Not only does it get him into inefficient habits of life, but also it is very apt to lead him into mischief. It does not seem at all logical to give a student three or more months of vacation each year when all that he can hope to receive after starting in practice is two weeks—and he will be lucky if he is allowed even that much on full pay. On the other hand, though, I do not believe that any professor should be required to give instruction during more than nine months in the year. He certainly needs all of three months free from his labor, not only for rest and recreation but also in order to mix with the world so as to prevent himself from dropping into a rut.

Another handicap under which you professors are working is the necessity for adjusting your courses and the amount of ground to be covered to suit the capacity of the average student rather than that of the man of superior ability and quicker perception. I recognize that in so doing you are not acting as free agents, because it is necessary to graduate a certain number of men each year, the main object being to give the largest amount of effective instruction to the greatest number of students, and not primarily to raise the course to the highest attainable limit of excellence. The solution of this difficulty lies, possibly, in the establishment throughout the country of trade schools and polytechnic institutions of low grade. If the United States is to succeed in its foreign trade, it must do so by increasing the efficiency of its artisans and mechanics through giving them sound, practical instruction in trade schools, as Germany has made a practice of doing of late years. Again, as there must be many "hewers of wood and drawers of water" in the engineering ranks as well as in all the other walks of life, these can best be instructed in polytechnic schools of lower grade, or even, perhaps, in the trade schools, in neither of which institutions should they be obliged to spend time on cultural study, but should be able to devote almost their whole effort to the acquisition of knowledge in the primary technics, and in learning how to earn quickly a comfortable living. The withdrawal of such men from the higher technical schools would enable the faculties thereof to set a higher requirement for graduation and to elevate the grade of mental capacity in the entire student body. In my opinion, the time is ripe for the speedy inauguration of a large number of such low-grade technical schools throughout the country. Their graduates could become quickly either skilled workmen or efficient junior assistants on engineering work; but the more ambitious of them could pursue their studies further by entering the universities and the high-grade technical schools. Moreover, they should be encouraged so to do by the establishment of scholarships that would enable the most intelligent of the said graduates to obtain thorough technical education without any pecuniary expense to themselves.

As to where engineering schools in general fail to attain the greatest practicable efficiency, permit me to quote you as follows from my reply to the late circular letter of the Carnegie Foundation for the Advancement of Teaching.

"They are least effective and successful in giving the students a broad education; in teaching them culture; in arousing their enthusiasm for the engineering profession; in enlightening them as to what that profession really is and as to the greatness of the career upon which they are about to enter; in giving them instruction concerning the history of engineering and the careers of its great leaders and most successful practitioners; in making them truly conversant with ethical matters, both general and technical; in teaching them how best to conserve their time and energy and how to obtain the greatest benefit from their technical course; in the inculcation of sound ideas of business and of life in general; in teaching them oratory, logic, and *savoir faire;* in giving them practical instruction as to how best to utilize engineering literature, both standard and current; and above all in making them such masters of their own language that they shall be able to read, write, and speak it with ease, grace, and effectiveness."

The question now arises as to what is best to be done in order to increase the efficiency of engineering courses. Next to a lengthening of their duration, I am of the opinion that the most effective way is to arouse immediately in their entering freshmen interest and enthusiasm for the engineering profession, and to keep the same alive as long as they are at school. I firmly believe that a gain of fully twenty-five per cent. in the general efficiency of the student body could be attained in this manner, provided, of course, that the students be thoroughly instructed as to how most effectively to utilize their time. Most students do their work in a half-hearted way, striving to accomplish only enough to give them passing marks and to enable them to graduate with their class; but they can be taught to become so interested in their studies as not to consider them a burden but a real pleasure. When they become convinced that it is a great privilege to be allowed to study for the noble profession of engineering, their progress will become almost phenomenally rapid. How many technical professors are there who take a strong personal interest in the welfare and progress of each of their students, and who go out of their way to give to them sound, friendly advice concerning the college course and the later professional career, or who direct their outside reading into effective and useful lines? Not many, I fear! They do not appear to consider that the doing of such things is a part of their duty; but it certainly is. The true teacher is the man who looks upon his students as his "boys," and who takes a pride in making fine men of them as well as in instilling into their minds the instruction which he is paid to impart. He should be not only their friendly mentor during the college career, but also their adviser in after life. They should be made to feel that they can go to him at any time when in difficulty of any kind, or when in need of technical information or friendly advice; and, undoubtedly, a great many of them will thus appeal to him in later life, if he does his full duty by them when they are under his instruction. It is men of this stamp—and such men only—who are truly fitted to teach; and any instructor who is glaringly deficient in this characteristic should be dropped from the faculty, no matter how great an investigator he may be or how efficient in other lines; for his proper place in the world is not in the teaching profession.

In connection with the subject of increasing students' personal efficiency, will you forgive me for possible egotism, if I make the statement that the book of "Addresses to Engineering Students," compiled and edited a few years ago by my firm, can readily be made the most effective possible aid in accomplishing this result? All that is needed is to make it requisite for each entering freshman to get the book and to peruse it from time to time. An occasional quiz would ensure his reading it; and with proper encouragement the better class of students would soon form a habit of glancing over parts of it during leisure moments instead of wasting their mentality on literary trash. No student or young engineer can read the book without receiving from it great benefit; for it represents the best thought of the engineering profession during a quarter of a century on matters relating to the welfare of young men at technical schools and after their graduation. I do not hesitate to urge you to insist on the purchase of the book by the entering freshmen, notwithstanding the fact that we were of necessity the publishers as well as the editors of the work, for the reason that it is sold at a trifle less than the actual cost of paper, presswork, binding, and freight. I make this explanation in order to forestall any possible thought that I am trying to advertise and profit pecuniarily from a business venture. I feel that unless I succeed in securing your aid in distributing annually this book, one of the most important efforts of my professional career will prove a failure.

Enthusiasm for the profession can be aroused in engineering students not only by the members of the faculty but also through lectures by successful engineers. Every course in engineering should be supplemented in this way to as great an extent as is practicable. It certainly encourages engineering students to greater effort by bringing them into personal contact with those who are engaged actively in doing the world's work.

In respect further to the question of efficiency, I desire to endorse heartily the movement, inaugurated by Professor H. H. Higbee, president of the executive council of Tau Beta Pi, to investigate the subject of "personal efficiency as applied particularly to studying and to college life"; and I sincerely wish that the consensus of opinion which he obtains may be the means of thoroughly informing the teaching profession upon this most important matter. It is to be hoped that the said consensus of opinion will soon be published and made available to the general public.

I am an ardent advocate of encouraging students to greater effort by holding out to them the possibility of attaining such scholastic distinctions as membership in Phi Beta Kappa, Sigma Xi, and Tau Beta Pi; and I believe that if a comparatively limited number of Phi Beta Kappa keys could be competed for annually on literary work by engineering classes, much good could be accomplished in the line of perfecting technical students in literature, language, and other cultural studies. Is this susceptible of accomplishment? I commend the question for your serious consideration.

The development in students of the ability to make correct judgments quickly is a matter that has not received much attention from technical instructors; but it is, nevertheless, one of importance. I believe that it would be practicable for the latter to attain a certain amount of success in this by requiring their students from time to time to pass judgment upon current issues, especially those of a technical nature.

The broadening of engineering courses so as to include many studies of a non-technical character is a great desideratum; and its importance cannot well be exaggerated. Among such studies are the following: English, a foreign language, political economy, ethics, history of engineering, oratory, logic, the science of government, evolution, physiology, bacteriology, general world history, engineering law, and the principles of business. Such studies will tend to make of the student an educated, polished gentleman, while those ordinarily given in technical schools are designed to make him only a technically trained engineer. Years ago when an engineer was considered by the public to be merely a superior sort of mechanic, culture studies were not necessary in engineering curricula; but it is otherwise today, for now the engineer has to mix much with his fellowmen in order to inaugurate and materialize public enterprises of great magnitude and importance. He can no longer show himself to society as a greasy mechanic or an out-at-elbows draftsman; but, instead, he must appear a polished, well dressed gentleman, of pleasing address and interesting conversation. Besides, he must show unobtrusively and naturally that he is a man of affairs, posted on sound business principles, self-possessed, and ready to engage in any kind of intellectual conversation on matters both technical and general. Such characteristics cannot well be developed in the purely technical school, but with the addition to the curriculum of well selected culture courses and by teaching them with the same degree of thoroughness as the technical branches are taught, the result desired is possible of accomplishment.

Very few technical schools pay much attention to the study of business, for their faculties fail to recognize the condition that engineering is a business as well as a profession. There should be a short but thorough course in accounting, as well as one in economics; because the valuation of existing properties is one of the really important tasks of the modern engineer. True economy in designing, construction, and operation is a prime necessity in engineering; hence the study of economics should receive due consideration.

A general knowledge of political economy is a requisite for every deep thinker—and who has to think more profoundly than the engineer?

The technical professor who does not teach his students how to utilize effectively engineering literature, both standard and current, fails grievously in his duty to them; for upon their ability to use the recorded experience of other engineers will depend in a great measure their professional success. Such teaching is by no means difficult, for it consists mainly in giving to the classes written instructions and setting their members individually to making library searches on various technical matters.

Professors should encourage their students to do a certain amount of reading outside of the regular course; and in order to make sure that this is not neglected, it would be practicable to have the individual students pass judgment upon new technical books and concerning matters of general interest that are dealt with in the engineering periodicals. Suitable books for such outside reading should be provided in the school library; and the professors should lay out courses therein for the different students, varying them to suit individual needs and peculiarities.

Lectures on the ethics of engineering should be given to all technical students; and the inculcation in their minds of high ideals in both professional and private life should never be ignored.

Why is it that the study of the English language is so neglected in most American technical schools? I think it must be because their faculties do not recognize that for an engineer of any standing it is the most important tool that he uses in his professional work. Without a proper command of it he is seriously handicapped in all business matters—and, as before stated, engineering is a business as well as a profession. In making written reports, in addressing meetings of directors, in holding conferences with government officials, in giving expert evidence in court, in delivering addresses to scientific or technical societies, and in all other public speaking an engineer to be truly successful must have a thorough command of his native language. To the acknowledged deficiency of engineers in general in this prime requisite for success is undoubtedly due the fact that our profession is not held in as high esteem by the public as is indisputably warranted by the great importance of the work done by its votaries. Even when a fairly good course in the English language is given in a technical school, the students, as a rule, neglect it for studies which they erroneously deem of greater importance.

In my opinion, English should be taught thoroughly and effectively throughout the entire course in every technical school; and I would prevent a student from graduating, were his final thesis defective in respect to language. This may strike some of you as being ultra-severe; but there is no more effective way possible of impressing upon the student body that they must not neglect their English work.

It is a mistake to have the regular instructors of a university teach the English language to engineering students; because they cannot be made to give due consideration to the technical man's needs. They are too prone to filling his mind with the English of ancient days and with classic literature and poetry, not recognizing that what he most requires is prose instead of poetry, and sound, forceful business-language instead of excessively polished phrases and super-refined diction. It is my opinion that English can best be taught to engineering students by a man who is himself an engineer, provided that he has made a special study of his native tongue and has the ability to impart his knowledge to others.

Not only should the student be taught to write clearly, concisely, and forcibly, but he should be given a thorough course in oratory, and should also be taught how to read technical papers with a smooth and pleasing delivery and so that everybody in the room can hear him distinctly.

I am a firm believer in the principle that the learning of English is greatly facilitated by the thorough study of at least one foreign language; and on that account I favor making such a study obligatory in every engineering course of instruction. Latin and Greek are of no real value, and are seldom studied with sufficient thoroughness to develop an adequate conception of language construction. Modern languages are far better; and engineering students should be taught to read, write, and speak one of them correctly and readily. In choosing a modern language for an obligatory course in any American engineering school one should certainly be governed by the consideration of utility; in other words it should be that language which is likely to be of the most service to the greatest number. A real knowledge of French is a gentlemanly accomplishment that is a great satisfaction to its possessor; but it is of no practical value to an American engineer. German is somewhat better in this particular, especially in hydraulics and the pure sciences; but no technical school aims to give its students more than merely a reading knowledge of it—and generally, it must be confessed, only a smattering one at that. As most of the German technical books that are of real value to American engineers are soon translated into English, it is evident that in respect to the enforced study of German in American technical schools, the game is not worth the candle.

With Spanish, however, it is an entirely different matter; for in times past many American engineers have worked in Latin-America; and the time is close at hand when the United States will begin to dominate the trade of all the Central American and South American countries. This much-to-be-desired result has to be accomplished mainly and primarily by its engineers; and to succeed in their efforts they must have a sound, working knowledge of the Spanish language, which, with the sole exception of Brazil, is the universal tongue in all the Latin American countries. Not only do I advise that its study be made essential in technical schools but also that it be made to supplant immediately Latin and Greek in high schools, colleges, and universities, and that it be chosen as the modern language to study instead of German or French. However, I do not believe in debarring American students from the opportunity to learn the two last mentioned tongues; but I would make the courses in them optional—at the same time giving them much more thoroughly than they are generally taught in the United States today.

As for the requisite sound drill in language construction—Spanish will be found just as useful as French or German and far better than either Latin or Greek. Concerning this matter I speak from personal experience, having studied all those languages except the German.

As far as I can learn, it is safe to state that, with very few exceptions, no foreign language is at all thoroughly taught in any of the schools, colleges, or universities of North America. By the proper teaching of any foreign language I mean that the students should be compelled to learn to read, write, and speak it correctly, fluently, and gracefully, and so as to understand it readily when they hear it spoken. Some of you may claim that such a result is impracticable of attainment in American schools; but if any such there be, I beg to differ with him *in toto*. On this point, too, I know whereof I speak; for I have seen in the short period of six or seven months with only three night lessons per week, each of an hour and a half or at most two hours' duration, young men and women of only average intelligence and ability learn to speak Spanish (somewhat haltingly it is true) and to comprehend it readily when heard. What then could not engineering students with their highly developed minds accomplish in a course given just as thoroughly and extended over a period of four or five years!

Much of the success of the students in foreign language courses depends upon the character of the instruction given and upon the personality of the instructor. It is absolutely essential that the language taught be the teacher's native tongue; or else that he be truly bi-lingual. Otherwise, the course will be doomed at least to partial failure. Again, language teachers are born—not made; and the instructor should teach according to the most approved and successful methods known. Moreover, he should be an enthusiast in his work and should take great pride in his accomplishment. Under these conditions I feel confident that the entire graduating class would truly possess a sound, working, business knowledge of the foreign language taught.

Let me impress once more upon each one and all of you the extreme importance at this time of the world's history for educated Americans and especially American engineers to learn to read, write, and speak the Spanish language.

In conclusion, I beg to thank you, gentlemen, for your kind attention, and once more to offer you my humble apologies for intruding into a field of professional activity, which, perhaps, I should not attempt to enter.

REFLECTIONS OF A DIRECTOR.

BY JOHN F. HAYFORD,

Director, College of Engineering, Northwestern University.

The announced title of my address leaves me with considerable freedom to talk on a great variety of topics, to make discontinuous remarks, to give you questions without answers. or answers which seem to me to be right without question.

As director of a new college of engineering for the past six years I have necessarily been forced to think upon many questions which probably arise in all colleges of engineering. I began that six-year period after seventeen years in engineering practice. It was but natural, therefore, that my point of view, at first, should be that of an engineer rather than that of a teacher of engineering students. During these six years I have reached conclusions on some topics which seem to be in accord with the general belief and practice among teachers of engineering. It is not worth while now to discuss these matters in which we are all in agreement. On some topics my conclusions apparently differ from those of the majority as indicated by the prevailing practice. Some of these conclusions I shall state. Some of my reflections have led mainly to questions which are still for me largely unanswered. A few of these questions will be stated.

It is of prime importance to the success of an organization that it shall be dominated by clearly defined ideals or purposes, and that little or partial ideals shall not be allowed in practice to crowd out the greater ideals. As applied to a college of engineering this means that every man on its teaching staff, or concerned in its administration, should have before him continuously the clearly defined ideals of the college and should be alert to detect conflicts between these greater ideals and the smaller or partial ideals which will inevitably be formed as one faces the details of the daily routine. If one approaches the work of a college of engineering with these convictions, certain broad questions soon stand out prominently.

What shall be adopted as the main purpose of a college of engineering? I believe the main purpose of a college of engineering should be to take the student who comes to the college with a good high-school training and to do as much as is possible in five years, and within the financial and other limitations of the college, to make him of the greatest value to the world as a man engaged in engineering as a profession in the next forty years after graduation.

It is a good ideal to make the engineering graduate as valuable as possible to his employer in the first five years after graduation. But it is a small and partial ideal, in conflict with a much greater ideal. For on closer examination it appears that for highest efficiency in the first five years after graduation, considerable emphasis must be placed on furnishing the student considerable skill and so-called practical information. On the other hand, if one is planning for the greatest efficiency in forty years the emphasis will be thrown on teaching principles, on laying the foundation for unlimited growth in expert knowledge, on turning out men who will be students all their lives. In a trade one offers his special skill to the world. In a profession one offers expert knowledge. A college of engineering should do its best to fit each of its graduates to follow a profession for a life time. In so far as the five-year trade ideal is in conflict with the forty-year professional ideal, we should ignore it, even though it is urged upon us by practicing engineers.

It is a good ideal to turn out engineering graduates who are thoroughly informed about engineering. But it is a small and partial ideal. There are many things which may be learned more quickly and effectively outside of college walls than inside, and vice versa. Shall we recognize this frankly in deciding what shall be taught during college days? If it is so recognized it will lead, in my opinion, to leaving to the years after graduation much of the acquisition of engineering information as to how things are being done. Theory, the understanding of the reason why things are done in a certain way, may be learned more effectively in college than outside. These reasons, the principles, are permanently useful and change but little. Engineering practice, the way things are done, changes rapidly and may be learned better outside of college than inside.

These remarks apply both to the way college courses are given and to the selection of the particular courses.

Of course the student should acquire a considerable fund of information about engineering practice while in college, from the many illustrations drawn from engineering practice and used in the class rooms to help arouse his interest and to make engineering principles concrete to him. The primary emphasis should, however, be placed on the principles rather than on the information.

Shall shop work be given with a view to developing a certain degree of manual skill on the part of the student and to giving him a large amount of information as to shop methods, or on the other hand, shall it be primarily a training in seeing the principles that are applied in shop practice? The latter seems to be the better plan. If that plan is followed, will it not lead to spending less time in the college shop than is now customary? Is it not well in fixing the shop course to remember also that a college shop can be in any case but a poor imitation of an actual shop, and hence that shop principles may be taught in the imitation shop much more efficiently than shop practice may be taught there?

Similarly, if one decides at the outset that the policy as to drafting is to give the student such a start that he may acquire the necessary skill easily, rather than to give him that skill, may not the time spent in drafting be considerably reduced?

Is it not true that the most frequent barriers to the greatest success of a given engineer are his lack of a sufficiently broad view of life, a lack of sufficient ability to see the broad aspects and bearings of an engineer's work, a lack of sufficient ability in dealing with men, in short, a lack of sufficiently broad foundations of character and thought? Can the college do nothing to help the future engineers in this respect? Some men seem to hold the view that soundness of character and breadth of thought are wholly inherited and that they cannot be developed. Is it not much nearer the truth to say that men inherit these things in varying degrees, that the students who enter our colleges from the high schools have them to very different degrees, but that in the impressionable college years much can be done both to develop soundness of character and breadth of thought? If so is it not advisable for us, as teachers of engineering, to look carefully to see if we are doing the best that can be done to develop our students along these two lines?

We may help to develop soundness of character partly by constructive discipline, partly by having proper advisory relations with the students, and partly by inculcating strict intellectual honesty. Is it not also true that soundness of character tends to be associated with breadth of view, and weakness of character with narrowness of vision? If so, then we are under a special obligation to help our students to acquire breadth of view.

In my opinion, breadth of view may be favored partly by the manner in which the courses are taught, even including the most technical engineering courses and partly by the selection of the courses which together make up the curriculum.

Assuming that the student of engineering is given more training in mathematics and physics than the minimum needed for engineering, it seems that the other broadening courses should ordinarily be selected from the liberal arts field and especially from the groups, foreign language, English, geology, economics, and psychology. If these courses are not broadening in their general effects, what college courses are? I personally am inclined to favor economics and psychology especially among the courses named, as tending strongly to give the typical engineering student new and broader views. If broadening comes largely from the manner in which teaching is done, are we not in duty bound to help to make certain that these general courses are well taught?

One of the questions that must be kept in mind at all times in fixing the policy of a college of engineering is this: What is the capacity of the average student? How much of new thinking can he be induced to do and how much new information can he secure during his college course? After all, even five years is a short time and the capacity of a student is limited. We all know that it would be easy to make out an engineering curriculum in which every course would be desirable and valuable and which a good student could not finish in less than eight years. We must put enough into our college curriculum, selecting courses in the order of their importance, to keep a student working up to his full capacity steadily.—otherwise we waste a part of his time. If we put in an amount that is beyond his capacity it is equally bad for him. Hence it is important to determine the student's capacity as accurately as possible. How shall this be done?

Possibly one may estimate whether the curriculum is beyond the capacity of the average student by noting the percentage of students who drop out each year under poor scholarship rules. This estimate would be defective, however, in several ways. How severe are the poor scholarship rules? In these days when it is the style to go to college and hence some students have primary interests unrelated to scholarship, what percentage of our students should be expected to fail even if the average student is worked merely up to his capacity? Do not many men drop out from discouragement when they are merely in danger of being caught by the poor scholarship rules but are not yet caught? If so, should we judge whether the curriculum is too full by the percentage of students who drop out from all causes? What is the normal percentage of waste from all causes which may properly be used as a standard?

I have been applying two other tests each year to determine whether our curriculum at Northwestern is too difficult.

All engineering students have been classified each year into three groups; first those registered for less than seventeen hours, second those with the normal registration of seventeen hours, and third those registered for more than seventeen hours. The students in the first group are largely those who have in earlier semesters shown that they are apparently unable to carry seventeen hours. In the third group are the few students who are behind their class but are believed to be capable of carrying more than seventeen hours. The average experience has been that the lightened load on the first group does not prevent them from falling considerably below the second group in their average grades. The few selected men in the third group usually carry their excessive load with a grade considerably higher than those in the second or normal group. My conclusion is that seventeen hours is about the full capacity load for our students. If it were an excessive load group one would do practically as well on an average as group two, and group three would tend to fall below. If it were less than a full capacity load the picked men in group three would tend to secure considerably higher average grades than those in group two, and group one would tend to fall considerably below group two.

Also in each year all engineering students have been classified in two groups, working and non-working students. A student is classified as working if he is spending six hours or more per week in work for his own support. Our average experience thus far is that the working students have carried 97 per cent. as many hours of registration as the non-working students, and have carried it with an average grade one point higher on the scale of 100.

However, all these tests combined still leave too much uncertainty as to whether the curriculum is accurately fitted to the capacity of the students. Do you know of any better tests? Of course you may say one should use his judgment in such a matter. I ask, upon what evidence shall the judgment be based? Have you any suggestions?

In the college of engineering with which you are connected do you visit each others' classes and does the dean or director of the college visit classes? If not, why not? If a very small percentage of such visiting is done, why not do more?

Do you maintain any cost system as a part of administration in your college to secure information as to the relative repairs and maintenance of buildings and equipment, for teaching salaries, and for overhead charges,—and to determine what effects any proposed changes will have on unit costs? If not, why not?

I have set forth some of my conclusions and stated some questions. I hope that there will be frank discussion of the conclusions and that answers to the questions will be offered. A discussion with the object of finally reaching correct conclusions will be beneficial to all and especially to me.

Discussion.

Dean W. G. Raymond: I have not much to offer. Professor Waddell likes to have his papers thoroughly discussed and always presents papers that invite considerable discussion, but to furnish adequate discussion of such a paper as this would require a paper of equal length. One point I want to speak of, applying also to Director Hayford's paper, at least to one point in it, and that is the effort we make to adapt our courses to the average student, not doing what we ought to do for the brighter student and for the slow but capable student. We lose the latter, and we do not do enough for the man capable of doing more than the average. Some of you know that I have on previous occasions offered a panacea. I am still offering it.

Principal A. L. Williston: I am sorry to rise to speak so often this morning but in the past papers one or two questions were asked. The paper by Dr. Waddell lays, quite properly I think we all agree, a great deal of emphasis on the development of soundness of character and breadth of view of the student, and asks very pertinently, what are the courses which will accomplish that, and later it suggests one of these courses, psychology. Further, the paper refers to the possible advisability of decreasing drawing and shop work and teaching less of the trade and more of the profession. If drawing and shop work are a development of the skill of the fingers and nothing more, we do not need much; but if, on the other hand, education is, as was claimed, a drawing out and developing and unfolding from within—as I think most psychologists and students of pedagogy agree today, then perhaps the other definition of drawing and of shop work is true—that which is a language, a means of expression of ideas that have grown within. The answer I would suggest as possibly one covering the question which has been raised is that these courses which would best develop soundness of character and breadth of thought are those courses which give the best opportunity for individual expression of ideas from within. In my own humble judgment, drawing and shop work are two of the very best for giving that opportunity, if they are rightly taught, really expressing individual character and individual thought, giving an opportunity for just the kind of growth the author of the paper desires.

Dean A. A. Potter: I am very much interested in the subject matter of the last two papers. In regard to the credit hours per week which a student should carry, this depends not only upon the student but also upon the subject and the teacher. In some cases a student having an assignment which consists mainly of non-professional or non-mathematical subjects, should be permitted to carry a load of twenty or even twenty-four credit hours. Another student who is taking up such mathematical subjects as theoretical mechanics may have to be limited to only seventeen or eighteen credit hours per week. The interpretation of the credit hour made by the instructors affects the carrying-capacity of the student. In the case of laboratory courses, some teachers hold their classes three hours in the laboratory and then require three or four hours outside of the laboratory for the preparation of reports, all for one credit hour. Other instructors will lecture one hour and require only one-half hour or one hour of outside preparation for one credit hour. If a careful standardization of the credit hour could be made by close supervision of teachers and teaching methods, the load to be carried by a student could be accurately adjusted and for best results.

In regard to Dr. Waddell's paper, I would like to see his suggestions tried out at some privately endowed institution. It is worth trying. Language study should be left mainly to the secondary school or even to the primary school. Boys at the ages of six to eighteen are more capable of acquiring a working knowledge of languages than they are after entering college. Advanced language studies should be offered as electives in the college course.

Professor R. H. Fernald: I, too, have been very much impressed by these two papers. Many of the suggestions appeal to me as sound.

The last speaker touched upon one point that I would like to hear discussed, namely, the question of units. As many of you know I have had the good fortune to be a rolling stone as I have been connected with several institutions both east and west. I have gotten, possibly unfortunately, the reputation of being a hard taskmaster as I require a large number of units from the students.

In two or three institutions, I have been assisted by very able assistant professors. Our work has, I believe, been carefully arranged and these assistant professors have offered valuable criticisms and suggestions. One criticism that has been made several times is that I asked too much of the student. In all of these cases the students are carrying far more than the seventeen units mentioned in the papers under discussion. This raises a question in my mind regarding the value of a unit as the papers presented imply that seventeen units make a reasonably heavy schedule. In one institution one of my assistant professors showed me that we were requiring at least one third more work of our students than was required at the Institute of Technology, and he felt that our schedule should be materially reduced. A careful review of the situation, however, showed that we were not failing to graduate men who should be graduated and that our students were carrying their work comfortably well.

Similarly, at another institution, a professor in charge of another engineering department brought out the same point. He felt that we were overworking the students, in fact driving the life out of them. He questioned whether the men could stand it—the work was so much harder than at Tech. His idea at that time was to materially reduce the number of required hours in his department, but, as far as I am aware, no such reduction has as yet been made.

During the past year at the University of Pennsylvania, several records have been made relating to this subject. Queries have been sent to the boys asking them to give us in detail the number of hours of outside work required each day of the week for each subject in the course. I have gone before the various classes explaining what was wanted and asking the students to supply the data, on the forms furnished, without their signatures. Some of the students told me frankly that they would not hesitate to sign their statements. The general supposition would be, I believe, that the average boy would tend to report ample outside preparatory time rather than to minimize his figure; that is, the attitude might be to exaggerate the time required per week. A review of the figures submitted shows that it is seldom that a boy puts in much more than an hour's preparation per hour of class room exercise on any subject and that the total time, including class room exercises and all outside preparatory work, amounts to about fifty-four hours a week. I consider this about right. In exceptional cases, in which the boy is carrying extra subjects, his total time per week may reach sixty hours. The question in my mind is, then, with a seventeen-unit schedule how do Dean Hayford and Dean Walker get a fifty-one hour week? The ratio of 3:1 has, I believe, been a common figure in the minds of educators for some time, but I doubt that returns from the student will often show two hours' preparation on any given subject. I shall be interested to know whether the fifty-one hour week on the seventeen unit basis is not a supposition rather than a statement of actual hours reported by the student.

Director J. F. Hayford: There are two questions I wish to answer put by Dean Potter and Professor Fernald. I want to call your attention first to the fact that I did not bring up the question of units or standardizing units or comparing units in one place with another. I put the emphasis on the determination of the capacity of your students in terms of the work you are giving them. It seems to me the first thing is to compare the capacity of your students with what you are asking them to do. Of course, you will then run into another question, the standardizing of the unit in your own institution. The important thing to look after is this—and Professor Bauer will affirm this proposition—to standardize the units in the sense that you prevent some professor from being predatory, taking the time others ought to get. Professor Bauer is not one of the offenders, so there is nothing invidious in my calling attention to him. In that sense, you need to look into the question of the unit. My impression is that making comparisons between different institutions is relatively unimportant. The important thing is to compare your requirements with the capacity of your students,—and perhaps incidentally to compare one professor with another in the same college.

Professor W. S. Bauer: I should like to corroborate what Director Hayford has said. I want to say, for the benefit of the last speaker, that Director Hayford never guesses at a thing. When he puts down a figure, there is a good deal of work behind it. The fifty-one hours is not guesswork. He has standardized our laboratory units so that I require no more than the professor of mechanical engineering requires for a unit.

REPORT OF JOINT COMMITTEE ON CLASSIFICATION OF COLLEGES.

You will doubtless remember that two years ago the United States Bureau of Education issued a circular classifying the colleges of this country. This report met with so much opposition that finally the President of the United States ordered the Bureau of Education not to issue a second edition. The Bureau, however, has thought for a long time that it should compile statistics of some kind in regard to American colleges, and publish them. If I read the minutes of a meeting recently held in Washington, it will explain what has been done.

MINUTES OF A MEETING OF THE COMMITTEE ON HIGHER EDUCATIONAL STATISTICS.

BUREAU OF EDUCATION, MAY 3, 1915.

The Commissioner of Education called the first meeting of a committee consisting of representatives of certain associations of higher educational institutions appointed to take up with the Commissioner of Education the desirability of classifying colleges and universities, for Monday, May 3, 10 A. M., at the office of the Bureau of Education.

The Call.

April 13, 1915.

My dear ———

You will doubtless remember that the Bureau of Education has been organizing, during the past year, a committee made up of representatives of the principal associations dealing with higher education to discuss with the Commissioner of Education the advisability of undertaking the classification of universities and colleges on a national scale, and, if such action seems desirable, to consider the best method of procedure. I have been informed that you have been appointed to represent the ———————— Association on this Committee.

It is very desirable that the Committee hold at least one meeting during the present academic year. I am, therefore, asking the members to assemble at the Bureau of Education May 3, 1915, at 10 A. M. I trust that it will be possible for you to be present.

I need hardly emphasize the very great importance of the action of this Committee. Its members have an opportunity to render an educational service of the first magnitude, and to remedy a situation which is causing many institutions serious embarrassment.

Sincerely yours,
(Signed) P. P. CLAXTON,
Commissioner.

The Membership of the Committee.

The members of the Committee and the association represented by each are as follows:

Professor Walter Ballou Jacobs, New England Association of Colleges and Secondary Schools.
Commissioner John H. Finley, Association of Colleges and Preparatory Schools of the Middle States and Maryland.
Chancellor J. H. Kirkland, Association of Colleges and Secondary Schools of the Southern States.
Professor H. A. Hollister, North Central Association of Colleges and Secondary Schools.
Dean B. D. Salisbury, Association of American Universities.
Chancellor Samuel Avery, National Association of State Universities.
Dr. N. P. Colwell. American Medical Association.
President Charles S. Howe, Society for the Promotion of Engineering Education.
President D. J. Cowling, Association of American Colleges.
The Commissioner of Education.

The members of the Committee were appointed by the several associations in accordance with the following resolution:

Resolved: That ———— Association appoint a representative to serve as a member of a committee, to which bodies named below will also be asked to send representatives to discuss with the United States Commissioner of Education the advisability of classifying colleges according to their standards and equipment, and, if deemed desirable, to decide upon a method of rating and to coöperate with the United States Bureau of Education in preparing classified lists.

The Association of American Law Schools has been asked to appoint a representative, but still has the matter under consideration.

Attendance.

In accordance with the call there met in the office of the Commissioner of Education, at 10 A. M., Monday, May 3, 1915, Professor Jacobs, representing the New England Association of Colleges and Secondary Schools; Mr. Horner, vice Commissioner Finley, representing the Association of Colleges and Preparatory Schools of the Middle States and Maryland; Professor Bert E. Young, vice Chancellor Kirkland, representing the Association of Colleges and Secondary Schools of the Southern States; Professor Hollister, representing the North Central Association of Colleges and Secondary Schools; Dean Salisbury, representing the Association of American Universities; Dr. Colwell, representing the American Medical Association; President Howe, representing the Society for the Promotion of Engineering Education; President Cowling, representing the Association of American Colleges; the Commissioner of Education and Dr. S. P. Capen, representing the Bureau of Education.

Chancellor Avery was absent and the National Association of State Universities was not represented.

The Meeting.

The Commissioner of Education opened the meeting and outlined the attempts of the Bureau of Education in 1911 and 1912 to classify the colleges of the country with relation to the value of the bachelor's degree. He explained why this undertaking was discontinued and summarized the reasons for going forward with it either in the same way or some other way, in the near future. He asked for an expression of opinion, from each member of the Committee, with regard to the desirability of proceeding with any sort of classification or critical listing of the colleges and universities of the United States. It was the unanimous opinion of the Committee that the desirability of continuing such work depended upon the method by which it was done. An informal discussion of the methods of classifying or listing colleges then took place, in which the following suggestions were made and approved by the Committee:

It was suggested that, if a classification or a critical statistical study were made, colleges and universities should be divided into different groups; for instance, a group of colleges and departments of liberal arts, another group of engineering institutions, a group of agricultural colleges, etc. It was suggested that eight or ten points relating to educational and administrative efficiency and to resources and equipment be decided upon; that a list of the colleges of the country (in several groups as suggested above) be made, and that there be recorded opposite the name of each institution its standing under the eight or ten points agreed upon.

Voted on motion of President Howe that the Committee undertake, in coöperation with the Bureau of Education, a study of colleges and universities in several groups, *e. g.*, colleges of liberal arts, colleges of agriculture, colleges of engineering; and that the principal facts developing from this study be tabulated and published.

Further discussion without vote dealt with the advisability of directing separate inquiries different in form to the several schools or departments or types of colleges to be studied. It was suggested that a separate form of inquiry should be devised for each of the following types of institutions: colleges of liberal arts and sciences, engineering schools, colleges of agriculture, schools of mines, teachers' colleges. It was understood that normal schools should not be included except as these are teachers' colleges.

Voted on motion of President Howe that no colleges be classified according to their relative rank, for example, as belonging to Class 1, Class 2, Class 3, etc.

Voted on motion of Professor Young that it is the sense of this meeting that this Committee of representatives of associations of higher educational institutions be continued, with the addition of certain other associations, as a permanent committee on higher educational statistics, to coöperate with the United States Bureau of Education.

Voted on motion of Dean Salisbury that the Commissioner of Education be chairman of this permanent committee.

Voted on the motion of Mr. Horner that Dr. Capen act as secretary of the permanent Committee.

It was then agreed that the points to be included in the inquiry to be sent to the colleges and universities of the country be informally discussed.

Voted on motion of President Cowling that the list of points when agreed upon by this Committee be submitted to all institutions claiming to be colleges or universities, for comment and further suggestion, before the inquiry is issued.

The following list of categories for recording the administrative efficiency and equipment of institutions, recommended by the Commission of the North Central Association of Colleges and Secondary Schools at the meeting of the Association held in March, 1914, was made the basis of discussion:

1. Number of faculty in independent charge of classes.
2. Number of faculty with the degree of Doctor of Philosophy.
3. Number of matriculated students.
4. Number of degrees granted in course.
5. Number of elementary courses of instruction actually given.
6. Number of advanced courses.
7. Number of professional courses.
8. Expenditures for salaries.

9. Hours of class instruction required of members of the faculty.
10. Material equipment.

Dean Salisbury moved that the first four categories be included in the list of points upon which information is to be sought by this Committee. Professor Hollister moved as an amendment that the topics covered by these four categories be edited and expanded by the secretary of the Committee and made a portion of the statistical inquiry. Dean Salisbury accepted the amendment and the motion as amended was carried.

Suggested by President Howe that category number 1 should reveal the proportion of under-instructors without much training or experience, and the distribution of the whole faculty among various ranks, as professor, assistant professor, etc. As far as may be this question should be an index to the quality of instruction offered.

Voted on motion of Dean Salisbury that categories 8, 9, and 10, subject to editing, be included in the inquiry.

Suggested that the inquiry include questions concerning the maximum and minimum salaries paid to each academic grade. It was further suggested that under category 10 the valuation placed by the institution on its campus not be counted.

The chairman then suggested six categories, as follows, partly coinciding with the ten listed above and partly different, which might properly be included in the inquiry:

1. The admission requirements; their administration. The treatment of conditioned students.
2. The requirements for degrees.
3. The faculty; number; training (number with master's degrees and doctor's degrees); salaries (the relative number of instructors of each class having the maximum and minimum salaries of the class).
4. Students; number and distribution.
5. Endowment and income (indebtedness).
6. Equipment; its present valuation.

After the presentation of these points by the chairman the members of the Committee suggested various other significant matters which the inquiry should include. These are summarized under different headings below:

A. Relating to the faculty:

The questions concerning the advanced degrees held by members of the faculty should be analyzed into so many master's degrees, so many doctor's degrees, etc.

The hours of class instruction required of members of the faculty should be differentiated, showing laboratory hours, lecture hours, and hours of class-room teaching.

If possible the inquiry should discover how many subjects are being taught by persons who have never had special preparation in them.

B. Relating to students.

The inquiry should include questions showing the requirements for special students.

It should indicate how long the requirements for admission and for degrees have been in force.

Graduate students should not be included in the inquiry. A supplementary list of questions should be framed for large universities and an attempt made to separate the graduate school from the undergraduate department of arts and sciences in the returns.

C. Relating to courses.

The ratio of courses announced in the catalogs to those actually given should be discovered.

The range of the college course should be indicated.

D. Relating to equipment.

The inquiry should include questions concerning the annual appropriation for laboratories. The appropriations for new materials and for maintenance should be differentiated. This is especially necessary in the case of technical and scientific schools.

The inquiry should include a question on the annual appropriation for the library.

Voted on motion of Professor Hollister that a committee consisting of Messrs. Capen, Salisbury, and Young be appointed to define the terms "college" and "university," and other terms relating to this inquiry, the definitions when approved by the whole Committee to be incorporated in the report as a suggested standard.

Voted that the blank to be used in the inquiry be prepared by the chairman and secretary and sent to the members of the Committee for suggestions, and that when the Committee's comments have been received and incorporated, the blank be sent back to the members once more for approval, and that it then be sent to the colleges and universities of the country for comments and suggestions before it is finally issued by the Bureau of Education.

Adjourned 4.30 P. M., May 3, subject to the call of the chairman.

(Signed) S. S. CAPEN,
Secretary.

It was afterwards decided to classify engineering degrees, also. Usually the United States Bureau of Education has absolutely omitted the higher degrees given by engineering colleges, and has asked only for Master's and Doctor's degrees given by the colleges, omitting the degrees of C.E. and M.E., etc., where they are given as advanced degrees. These will be included in the list which the Bureau publishes in future.

I shall be very glad to answer any questions in regard to the methods to be followed, or concerning any suggestions which came up in connection with this report.

C. S. HOWE.

DISCUSSION.

President C. S. Howe: When the former report was published by the United States Bureau of Education, it was issued without consulting the colleges. In most cases, the colleges were classified without having been visited; the classification being made by a man sitting in his office at Washington. You have heard the plan suggested in this report. In the first place, the educational associations have appointed members of the committee to coöperate with the Bureau of

Education. This committee will formulate certain questions to be asked, and then these questions will be sent to all the colleges for their comment and approval before they are sent out in a form to be answered. So, you see, the colleges themselves are going to indicate what the form of inquiry shall be. It will not be an inquiry made by the Bureau of Education itself. This plan has received the hearty support of the United States Commissioner of Education.

Dean C. Russ Richards: The chair would like to inquire if the work of this Committee is to be carried on yearly.

President Howe: I do not know. The first thing to do was to decide upon a series of questions to be asked of the different institutions. Probably the work of the committee will appear in tables continued from year to year, although this was not definitely discussed at this meeting.

Dean P. F. Walker: There is one question I want to ask Dr. Howe. In speaking of the matter of securing information as to members of the different faculties, their degrees, etc., it occurs to me that the matter of giving degrees is in an unsatisfactory condition; and my question is as to whether the committee with which Dr. Howe is working has considered the matter of listing the members of the faculties with reference to their membership in the national societies, such as the American Society of Civil Engineers, the American Institute of Electrical Engineers, and so on?

Professor F. C. Caldwell: President Howe spoke of listing the faculties according to their degrees. The situation as to advanced degrees in the various lines of work is so different that some care should be used in such a listing scheme. For instance, in at least one college, there is a rule that a man must have a doctor's degree before he can be made a full professor; whereas, in engineering colleges even the master's degree is not regarded as at all essential, provided the man has the needed education and experience.

I should like to ask was that storm brought on by the classification of the colleges, or by what they felt was injustice in the method? In other words, are the colleges willing to abide by the classification if they have their own way of being classified? Or will there be some storm again when the report of the committee is published?

President Howe: Of course, I can speak for only one institution, and give only my impression regarding others. I think the colleges were very much aroused by the first report on account of its injustice; and secondly, because of the fact that that work was the work of one man, and that man had, in many cases, not seen the colleges he classified. I have never seen any signs of unwillingness on the part of any college to give to the Bureau of Education any facts connected with it. I doubt if any college would object to giving the facts to the Bureau. The Bureau thinks it would be of great value to the colleges and to the public to have certain statistics published.

REPORT OF THE JOINT COMMITTEE ON ENGINEERING EDUCATION.

In the absence of the chairman, Mr. Desmond FitzGerald, Dean G. C. Anthony presented a report of progress for the Joint Committee on Engineering Education.

REPORT OF THE COMMITTEE ON THE TEACHING OF MECHANICS TO STUDENTS OF ENGINEERING.

Discussion of mechanics is regarded by some as more or less of a joke. Yet the committee I represent today was appointed by you, so the joke, if impending will have been perpetrated by yourselves. As I reported briefly a year ago, it took about a year to find out what we might do to interest the Society and during the past year we have made a few efforts to do something. Yet we have not reached a point where we are prepared to make any definite recommendations to this convention. The work we have done has been devoted to the preparation of a syllabus on the subject of dynamics, which is one of the things which I think the Society is expecting from the Committee. Three papers are being distributed to you, and two of them represent syllabi of this subject. The third paper consists of a number of extracts from different text-books on the subject, the extracts forming a very brief exhibit of a few of the things that have been written about in the journals which members of this Society usually see and otherwise much discussed. *Science,* for instance, during the last six months has contained several very interesting papers from members of the Society and others on subjects which the committee is working on.

The two syllabi are, one by Mr. William Kent and the other by myself. I regret that Mr. Kent is not here to explain more or less at length what he has prepared in the way of a syllabus. I do not intend to make any remarks about his syllabus, but in justice to Mr. Kent I wish to make a few corrections of typographical errors.

The syllabus entitled "Syllabus of Dynamics for Students of Engineering Who Understand the Simpler Elements of Calculus" is a first draft for committee consideration and not a recommended final form. I wish to explain that the syllabus is intended for students of engineering who have had a preliminary course in the same subject. I think in most engineering schools students are taken over this subject twice; first, in a more or less elementary way, generally given by the department of physics, involving no use of calculus; and then, at a subsequent time, the students are taken over the course again, sometimes by the department of mathematics, sometimes by the department of physics, sometimes by a separate department whose main job is the teaching of mechanics to engineering students. This syllabus is intended for this second course in dynamics. The students have had the preliminary course, with a large number of lecture room demonstrations bringing home the various principles, and also more or less actual laboratory work. The second course is slightly more formal and slightly more mathematical in character, and involves the use of simple calculus.

I think the syllabus is rather orthodox, and I do not intend to explain it all. Those of you who have not forgotten all about dynamics will find it quite familiar. I wish to mention, however, in some detail the fifth chapter of the syllabus, the one entitled "Some Fundamentals of Dynamics," beginning on page 266.

The first thing is the definition of the word "force." Probably this is not acceptable to all of you, but it is put in simple language and probably conveys the idea sufficiently well for the class of students we have in mind.

In the definition of the word "weight," attention is called to the fact that the word has several meanings; first, to denote the "heft" of a thing, or its earth-pull; second, to denote the amount of material in it. These things are surely quite different. Some writers insist on one meaning, some on another, and some permit the use of both meanings.

Under "quantity of material" is noted how we express it—usually by stating the volume of the thing or by telling how much it weighs (what the earth-pull upon it is). Some writers and teachers use the word "mass" to express the quantity of material when measured in the second way—that is, by weight. Many writers use the word ''mass'' in still another sense, which I will mention in a few moments.

We have, in the next paragraph, a few remarks on ''standards of weights,'' and in the next paragraph some remarks on various ''units of force.'' Then there follow two laws which are designated Law ''A'' and Law ''B.'' The discussions to which I referred a moment ago relate in a large part to the question, what is the fundamental law of dynamics? I have tried to dodge the issue and call one ''Law A'' and the other ''Law B.'' Law A is stated in italics on page 269 as follows: ''When a body is subjected to two forces (or two resultants) in succession so as to make the body move in a straight line, then the accelerations in the two motions are directly proportional to the forces (or resultants).''

This is the law which has been championed in the magazines and before this Society by Professor E. V. Huntington of Harvard. This law leads directly to equation 2, wherein one of the forces is gravity, or earth-pull.

I will read paragraph 7 on ''Inertia; Mass.'' Each term has several meanings in the literature of the subject. ''Experience teaches that a body at rest is disposed or incined, so to speak, to remain at rest indefinitely; it moves, if at all, because of the action of some other body upon it. Likewise, if a body is moving in a straight line (rectilinear motion) at constant speed, it inclines to remain in that state; any change in speed or direction of motion comes about only through the action of some other body. This reluctance or inability of a body unaided to move itself or change the amount or direction of its velocity is called inertia; and we say that all bodies are inert. In this sense of the words, all bodies have inertia or are inert in the same degree—just as all dead animals (large and small) are equally dead.'' This is followed by the definition, on page 270. On the next page I have tried to state clearly the different senses in which the word ''pound'' is used. We speak of one pound of force, to mention a certain amount of force; one pound of mass, and so on.

Then comes Law B, which is a law asserted by many very careful students to be the fundamental law of dynamics. Professor L. M. Hoskins, of Leland Stanford Jr. University, a member of our Committee, the oldest and most experienced teacher on the Committee, insists that this Law B is to be regarded as the fundamental one. It relates to the action of forces upon two different bodies, and is as follows:

"If two bodies be subjected separately to two single forces (or resultants) so that the bodies have rectilinear motion, then their accelerations will be directly proportional to the forces and inversely proportional to the masses respectively."

This leads very readily to equation number 8, perhaps a form more familiar than equation (2) or even (3).

$$\frac{F}{ma} = K, \text{ or } F = Kma.$$

In regard to the constant K, most writers select units of mass and acceleration so as to make K one. That was done when the C.G.S. system was devised. The committee which devised that system decided to make a new unit of force for the express purpose of making K one in that equation. K can be made one in another way, and there are writers who have invented other new units, always with the idea of making K one. It is not necessary to make K equal one. There are some advantages in leaving K there. One may get along without new units by determining the proper value of K, and there are some writers who prefer to do that.

The following tabulation affords a sketchy comparison of four schemes for developing a basal equation of dynamics. The first and second begin with Law A; they differ in their treatment of mass. The first ignores mass; the second gives it a place but secondary to weight. The second two schemes begin with law B. They differ in choice of units for F and m. Familiar units retain K; (certain) unfamiliar units dispense with it. The advantages and disadvantages of each of these schemes have been pointed out again and again, but in spite of all the discussion, no scheme seems to win general favor.

1. $F/F' = a/a'$; hence $F = (W/g)A$. Familiar units for F and W; mass practically ignored. Momentum $= (W/g)v$; kinetic energy $= \frac{1}{2}(W/g)v^2$; etc.
2. $F/F' = a/a'$ but $F = (W/g)a = ma$. Familiar units for F and W; mass given more or less prominence. Momentum $= mv$; kinetic energy $= \frac{1}{2}mv^2$; etc.
3. $F = Kma$. Familiar units used for F and m; then $F = (m/g)a$ and $W = m$. Momentum $= (m/g)v$; kinetic energy $= \frac{1}{2}(m/g)v^2$; etc.
4. $F = Kma$. $K = 1$ and $F = ma$; unfamiliar units, (dyne) for F or (slugg) for m. $W = mg$ or $m = W/g$; momentum $= mv$; kinetic energy $= \frac{1}{2}mv^2$; etc.

As I have already stated, the committee is making no recommendations now. It is not unlikely that we shall find it advisable to present the essential facts so far as possible bearing on the subjects in controversy, for your information, without attempting to make recommendations on the points most in controversy.

The whole subject is open for discussion in the time remaining. I will be glad to see that the committee very soon gets the benefit of your remarks. I would like very particularly to have your remarks on the definitions of the words "weight," "mass" and "inertia," and I would like also to have your remarks upon the points involved in the foregoing tabulation.

SYLLABUS OF DYNAMICS FOR STUDENTS OF ENGINEERING WHO UNDERSTAND THE SIMPLER ELEMENTS OF CALCULUS. SUBMITTED TO THE S. P. E. E. COMMITTEE ON MECHANICS, JUNE, 1915.

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Chapter I. Rectilinear Motion of a Point.

1. *Velocity.*—The motion of a moving point is called uniform or non-uniform according as the point does or does not describe equal distances in all equal intervals of time during the motion. In either case, *velocity* means the rate at which the moving point is describing distance. Obviously this rate or velocity is constant in a uniform motion and variable in a non-uniform one. For stating values of velocities, it is customary to take as unit velocity, the velocity of a point which has uniform motion and is describing unit distance in unit time. Thus we use the mile per hour, foot per second, etc.

2. The velocity in a uniform motion may be computed from

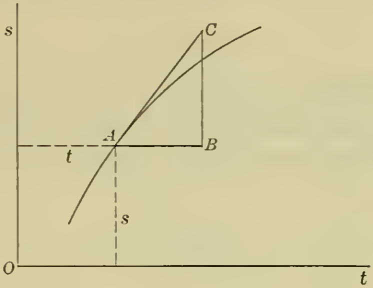
$$v = \Delta s / \Delta t, \tag{1}$$

where v denotes velocity, Δs the distance described by the moving point in any interval Δt.

For a non-uniform motion, $\Delta s/\Delta t$ is the average velocity for the interval Δt. This ratio is an approximate value of the velocity at any instant in the interval Δt; the shorter the interval, the closer is the approximation. If the mathematical relation between s and t is known, s denoting the (varying) distance of the moving point from a fixed origin in the path at any "time" t, then the velocity can be computed from

$$v = ds/dt. \tag{2}$$

3. The curve which represents the relation between s and t (see preceding article) is called the distance-time graph for the motion under consideration. Its slope at any point represents the velocity of the moving point at the corresponding value of s or t. The slope at A is the ratio of the length CB to length AB; the velocity equals (BC, to scale of s) $\div$ (AB, to scale of t).



4. *Acceleration.*—If the velocity of a point is changing, the motion is said to be uniformly or non-uniformly accelerated according as the velocity does or does not change by equal amounts in all equal intervals of time. In either case the rate at which the velocity is changing at any instant is called the acceleration For stating values of acceleration it is customary to take as unit, the acceleration of a point whose motion is uniformly accelerated and in such a way that the velocity changes by a unit amount in unit time. Thus we have one mile per hour per second, one foot per second per second, etc.

5. For a uniformly accelerated motion, the acceleration may be computed from

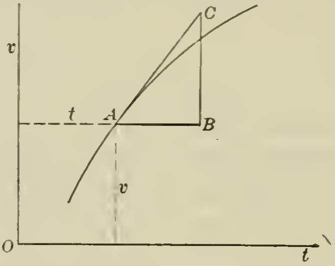
$$a = \Delta v/\Delta t, \tag{3}$$

where a denotes acceleration, and Δv the velocity-change in any interval of time Δt.

For a uniformly accelerated motion, $\Delta v/\Delta t$ is the average value of the acceleration for the interval Δt. This ratio is an approximate value of the acceleration at any instant in the interval Δt; the shorter the interval, the closer is the approximation. If the mathematical relation between v and t is known, v and t denoting corresponding values of the (varying) velocity and "time," then the acceleration can be computed from

$$a = dv/dt. \tag{4}$$

6. The curve which represents the relation between v and t is called the velocity-time graph for the motion under consideration. Its slope at any point represents the acceleration of the moving point at the corresponding value of v or t. The ratio (CB, to scale of v) ÷ (AB, to scale of t) equals the acceleration at the instant corresponding to A.



7. *Displacement and Velocity Change.*—If the velocity-time law for a motion is known, then the displacement Δs of the moving point for any interval Δt, or $t_2 - t_1$, can be computed from

$$\Delta s = \int_{t_1}^{t_2} v dt. \tag{5}$$

This formula follows from equation (2). From equation (1) we have

$$\Delta s = v_a (t_2 - t_1) \tag{6}$$

where v_a means average velocity for the interval $t_2 - t_1$. If the velocity varies uniformly, then $v_a = \frac{1}{2}(v_1 + v_2)$ where v_1 and v_2 are the values of the velocity at the beginning and end of the interval.

If the acceleration-time law for a motion is known, then the velocity-change Δv in any interval Δt, or $t_2 - t_1$, can be computed from

$$\Delta v = \int_{t_1}^{t_2} a dt. \tag{7}$$

This formula follows from equation (4). From equation (3) we have

$$\Delta v = a_a (t_2 - t_1) \tag{8}$$

where a_a means average acceleration for the interval $t_2 - t_1$. If the acceleration varies uniformly, then $a_a = \frac{1}{2}(a_1 + a_2)$ where a_1 and a_2 are the values of the acceleration at the beginning and end of the interval.

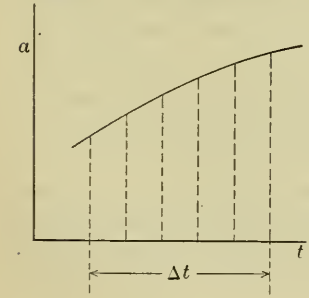
If the acceleration-distance law for a motion is known, then the change in the velocity-square $(v_2^2 - v_1^2)$ can be computed from

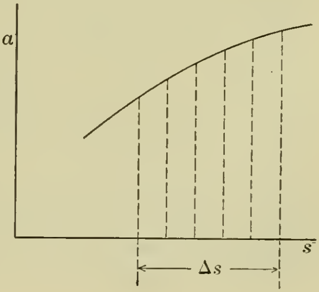
$$v_2^2 - v_1^2 = 2 \int_{s_1}^{s_2} a ds, \tag{9}$$

where s_1 and s_2 are the values of s corresponding to the velocities v_1 and v_2 respectively. The formula follows from a combination of (2) and (4). In a uniformly accelerated motion, where a is constant, equation (9) becomes

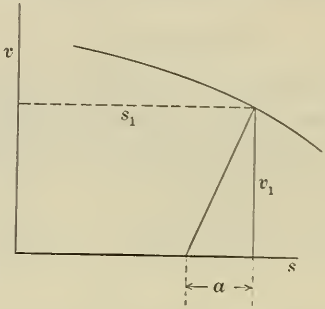
$$(v_2^2 - v_1^2) = 2a(s_2 - s_1).$$

8. *Motion Graphs.*—In addition to the graphs mentioned in Arts. 3 and 6, the following are more or less useful:





The first is an acceleration-time graph showing how acceleration varies with the time. ''Area under the curve'' represents velocity-change for the interval Δt. The second is an acceleration-distance graph showing how acceleration varies with respect to ''distance.'' Area under the curve represents twice the change in the velocity-square for the displacement Δs. The third is a velocity-space graph showing how velocity varies with ''space.'' Any subnormal as a represents the acceleration of the motion at the instant t_1; that is, when the velocity and ''space'' are v_1 and s_1 respectively.

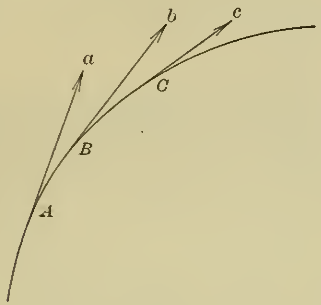


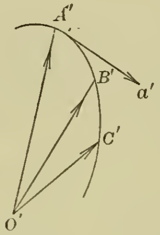
Chapter II. Curvilinear Motion of a Point.

1. *Velocity.*—All definitions and formulas of Arts. 1, 2, and 3, Chap. I, hold for curvilinear motions also. But in this type of motion there are certain advantages in regarding velocity as a vector quantity, or as having a distinct direction —as well as magnitude—at each instant; the direction is that of the motion (tangent to the path of the moving point) at the instant. Thus, if ABC is the path of a point P moving from A toward C, the velocity of P when at A is represented by the vector Aa; when at B, by the vector Bb; etc.

The words speed and velocity are generally used synonomously but some writers use speed to denote magnitude of velocity; this usage is very convenient and is followed in the subsequent articles.

2. *Velocity-change; Hodograph.*—Let v_1, v_2, and v_3 denote the speeds (magnitudes of the velocity) of the moving point P when at A, B, and C respectively (see figure). The increments in the speed for the intervals while P passes from A to





B and B to C equal respectively $v_2 - v_1$ and $v_3 - v_2$. The increments in the velocity are respectively vector Bb — vector Aa, and vector Cc — vector Bb. To determine a velocity increment—for the motion from A to B for example—we draw from the same point two vectors $O'A'$ and $O'B'$ to represent the velocities at the beginning and end of the interval respectively; then vector $A'B'$ represents the (magnitude and direction of the) velocity-increment.

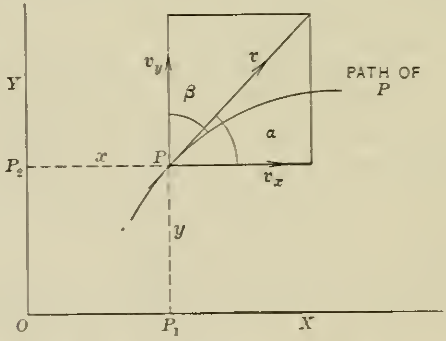
Let $O'C'$ represent the velocity of P when at C, and imagine other vectors drawn from O' to represent the velocities of P at still other points in its path; then the smooth curve drawn through $A'B'C'$ etc., is the hodograph of the motion of P; points A', B', C', etc., are said to correspond to A, B, C, etc.; the (moving) point in the hodograph which thus corresponds to the (moving) point P will be called P'.

3. *Acceleration* of a moving point at any instant is the rate at which the velocity—not speed—is changing then. The concept of the rate of change of a vector quantity is arrived at very much as we arrive at the concept of the rate of change of an ordinary (scalar) quantity (having magnitude only). Thus in the case before us, let Δt be the interval of

time while P moves from A to B; then the average acceleration during this interval is given by (vector $A'B'$) $\div \Delta t$. This is a vector whose magnitude and direction respectively are (length $A'B'$) $\div \Delta t$ and $A'B'$. If we take B closer and closer to A—Δt then getting smaller and smaller—this average acceleration approaches closer and closer to the ("instantaneous") acceleration of P when at A.

It will be noted that the average acceleration of P is also the average velocity of P'; hence the acceleration of P at A is also the velocity of P' when at A'; it is understood that distance on the hodograph is to be measured off by the scale according to which $O'A'$, $O'B'$, etc., were laid off. The direction of the velocity of P' (when at A') is $A'a'$, hence the direction of the acceleration of P is $A'a'$. In general, the direction $A'a'$ of the acceleration of P does not coincide with $O'A'$, that is the acceleration of a moving point is not directed along the tangent to its path—excepting in two cases as noted later; but is directed from the moving point toward the concave side of its path.

4. *Components of Velocity.*—Let P (see figure) be a moving point; x, y, and z its (varying) coördinates with respect



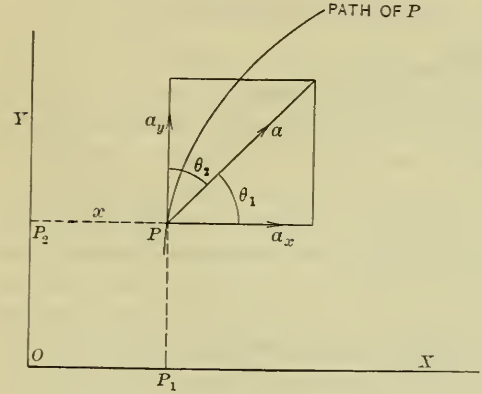
to coördinate axes OX, OY and OZ. (For simplicity and clearness only, the path of the moving point is represented as a plane curve, in the plane XOY). Also let v denote the speed (magnitude of the velocity) of P; v_x, v_y, v_z, the components of the velocity parallel to the coördinate axes; and α, β, and γ the angles between the coördinate axes and the direction of the velocity (tangent to path at P). Then

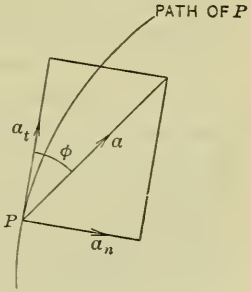
$$v_x = v\cos\alpha = \frac{dx}{dt}, \quad v_y = v\cos\beta = \frac{dy}{dt}, \qquad v_z = v\cos\gamma = \frac{dz}{dt}. \tag{1}$$

That is, the component velocities respectively equal the rates at which the coördinates of the moving point vary.

If P_1, P_2, and P_3 are the projections of P on the coördinate axes, then v_x, v_y, and v_z equal the velocities of P_1, P_2 and P_3 respectively.

5. *Components of Acceleration.*—In addition to the notation of the preceding article, let θ_1, θ_2, and θ_3 denote the angles between the direction of the acceleration of the moving point at any instant and the coördinate axes; a the acceleration of P, and a_x, a_y and a_z the components of the acceleration parallel to those axes (see figure).





Then

$$a_x = a\cos\theta_1 = \frac{dv_x}{dt}, \quad a_y = a\cos\theta_2 = \frac{dv_y}{dt}, \qquad a_z = a\cos\theta_3 = \frac{dv_z}{dt}. \tag{2}$$

It will be noted that the component acceleration parallel to each axis equals the rate at which the component of the velocity parallel to that axis is changing; also the component acceleration parallel to each axis equals the acceleration of the projection of the moving point on that axis. From equations (1) and (2), it follows that

$$a_x = d^2x/dt^2, \quad a_y = d^2y/dt^2, \quad a_z = d^2z/dt^2.$$

6. Let a_t and a_n denote the components of the acceleration of the moving point P parallel to the tangent and the normal to the path at P (see figure), r the radius of curvature of the path at P, and ϕ the angle between the acceleration and the tangent at P. Then

$$a_t = a \cos \phi = \frac{dv}{dt}, \quad \text{and } a_n = a \sin \phi = \frac{v^2}{r}. \qquad (3)$$

It will be noted that a_t is the rate at which the speed changes.

Chapter III. Motion of a Rigid Body (See Chap. VII also).

1. *Motion of Translation* is a motion in which each straight line of the moving body remains fixed in direction; there is no turning about of any line of the body. The coupling or side rods of a locomotive running on a straight track have a motion of translation. It can be shown that, in such a motion, all points of the body move alike; at each instant all points have the same velocity and the same acceleration. Hence the motion of the body is completely described by describing the motion of any one point of the body; velocity and acceleration of the body mean velocity and acceleration of any of its points. Obviously a motion of a body in which each point moves in a straight line is a motion of translation; this is the most common case of translatory motion.

2. *Rotation about a Fixed Axis.*—A rotation is a motion of a rigid body such that one line of the body, or of its (imaginary rigid) extension, remains fixed. This fixed line is the "axis of rotation." Obviously all points of the body, except those on the axis if any, move in circular arcs whose planes are

perpendicular to the axis and whose centers lie on the axis. The plane through the center of gravity and perpendicular to the axis is called the plane of the rotation; the intersection of the axis and this plane is called center of the rotation.

3. Angle described, or turned through, by a rotating body in any interval of time means the angle described by a line of the body perpendicular to the axis of rotation. *Angular velocity* of a rotating body means the rate at which it turns or describes angle. If the body rotates uniformly (describing equal angles in all equal intervals of time) then the angular velocity is constant, and its value is given by

$$\omega = \Delta\theta/\Delta t, \tag{1}$$

where $\Delta\theta$ means the angle described in the interval of time Δt. If the body does not rotate uniformly the angular velocity is not constant; $\Delta\theta/\Delta t$ is the average value of the angular velocity for the interval Δt. The value of the angular velocity at any particular instant is given by

$$\omega = \lim \frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt}, \tag{2}$$

it being understood that Δt always includes the instant in question.

The foregoing formulas for angular velocity imply that the unit angular velocity is the velocity of a body rotating so that it describes unit angle in each unit time; that is one revolution per minute, one radian per second, one degree per second, etc.

4. *Angular acceleration* of a rotating body means the rate at which its angular velocity is changing. If the angular velocity is changing uniformly (equal velocity-changes in all equal intervals of time) then the angular acceleration is constant, and its value is given by

$$\alpha = \Delta\omega/\Delta t, \tag{3}$$

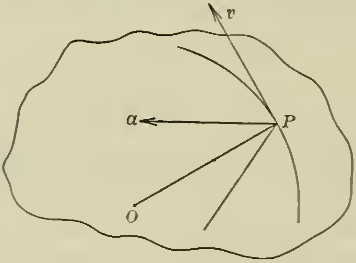
where $\Delta\omega$ means the change in the angular velocity in any interval Δt. If the angular velocity is not changing uniformly, then the angular acceleration is not constant; $\Delta\omega/\Delta t$ is the average angular acceleration for the interval Δt. The angular acceleration at any particular instant is given by

$$\alpha = \lim \frac{\Delta\omega}{\Delta t} = \frac{d\omega}{dt}, \tag{4}$$

it being understood that Δt always includes the instant in question.

The foregoing formulas imply that the unit angular acceleration equals the angular acceleration of a body rotating so that its angular velocity changes by a unit amount in each unit of time; that is one revolution per minute per minute, one radian per second per second, etc.

5. The angular velocity and acceleration of a rotating body at any instant completely define its state of motion at that instant. From their values it is possible to compute the



(linear) velocity and acceleration of any particular point of the body. Let P (see figure) be any point of a rotating body (represented by the irregular outline), O the foot of the perpendicular from P to the axis of rotation, and let $r = OP$, $v =$ the speed of P, $a =$ its acceleration, a_n and $a_t =$ the components of P along the perpendicular to OP. Then it being understood that ω and α are expressed in radians per ——,

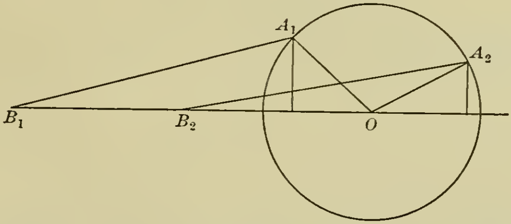
$$v = r\omega,$$
$$a_n = r\omega^2 \quad a_t = r\alpha$$
$$a = r\sqrt{\omega^4 + \alpha^2}.$$

6. *Plane* (*or Two-Dimensional*) *Motion* of a rigid body is

a motion in which each point of the body remains at a constant distance from a fixed plane. The (moving) connecting rod of a stationary engine has a plane motion; so have the wheels of a locomotive when it is moving on a straight track; and rotation about a fixed axis is a plane motion. A translation may or may not be a plane motion.

Generally, lines of the moving body parallel to the plane of the motion do not remain fixed in direction; they describe or sweep out angles. "Angle described by the body" means the angle described by any of these lines. Angular velocity of the body at any instant means the rate at which it is describing angle then; and angular acceleration at any instant means the rate at which its angular velocity is changing then. These two definitions are precisely like those of angular velocity and acceleration of a rotation about a fixed axis; hence the formulas for and units of angular velocity and acceleration of a rotation apply to any plane motion also.

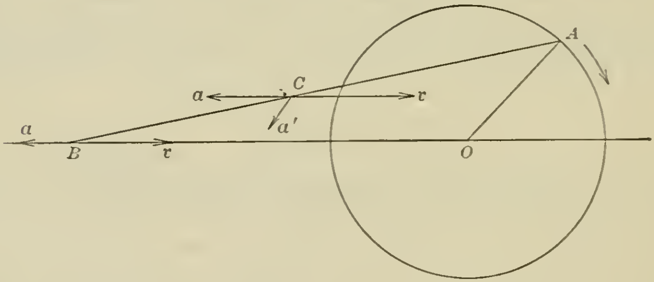
7. Any plane (two-dimensional) displacement of a body can be accomplished by a translation of the body followed by a rotation, or vice versa. For example, consider the displacement of the connecting rod AB of a stationary engine from position A_1B_1 to A_2B_2 say (see figure). The displacement might be accomplished by transporting the rod toward the right a distance B_1B_2 and then rotating the rod clockwise about B_2 through an angle equal to the angle between A_1B_1 and A_2B_2. Or, the rod might be rotated first about B_1 clockwise through the angle mentioned, and then transported toward the right a distance B_1B_2. Still otherwise: the rod might be moved parallel to itself until A_1 reaches its final



position A_2 and then rotated clockwise through the angle; or the rod might be rotated first clockwise about A_1 and then translated into the position A_2B_2. Evidently the rotation and translation need not be successive; that is they might be made simultaneously. The point about which the rotation is supposed to be made is called base-point. It is worth noting that the amount of the translation depends on the base-point selected but the amount of rotation does not.

Each successive small displacement of any actual plane motion may be reproduced by a simultaneous translation and rotation. The same point might be taken for all the small translations, and so any plane motion may be conceived as consisting of a succession of infinitesimal simultaneous translations (all with same base point) and rotations (about that point).

In accordance with this conception the velocity of any point of the moving body at any particular instant consists of two components, one corresponding to the translation and one to the rotation. For example, let us take B (see figure) as base-point; and let v be the velocity of B, ω the angular velocity of the rod, and r the distance of any point C of the rod from B. Then the two components of the velocity of C are v and $r\omega$ as indicated.



Similarly, the acceleration of any point of the moving body at any particular instant consists of two components, one corresponding to the translation and one to the rotation. Thus if a denotes the acceleration of B, and α the angular acceleration of the rod, then the components of the acceleration of C are a and a' as marked; a' consists of a component $r\omega^2$ from C toward B, and a component $r\alpha$ perpendicular to CB (see Art. 5).

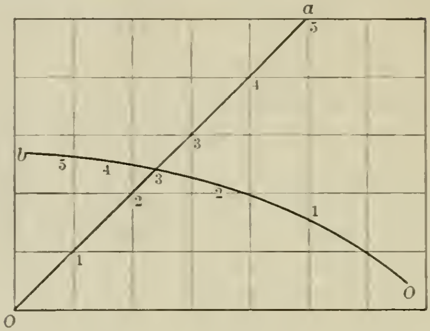
8. *Solid* (*or Three-Dimensional*) *Motion of a Body.*—This kind of motion may be regarded, just as a plane motion may be (see Arts. 6 and 7), as a combined translation and rotation. For obviously, any three-dimensional displacement of a body from one position A into another position B can be accomplished by means of a translation which would put some one point O of the body into its final position (in B), and from this (intermediate) position the body could be put into its final position by means of a rotation about some line through O. Evidently the translation and the rotation could be made simultaneously. Therefore, any actual motion of a body, from one position into another, may be regarded as a succession of infinitesimal simultaneous translations and rotations. All the translations may refer to one base point, but the successive rotations would not, in general, occur about the same line of the body.

Chapter IV. Relative Motion.

1. *Specification of Position.*—Position of a point can be specified only by means of a set of reference axes or some other equivalent device or "base." For example, when we say that a ship A is 30 miles east and 40 miles north of another ship B, we are really specifying the position of A with reference to the meridian and the parallel through (the point) B. If an observer on B says that A is 50 miles "broad off the port bow," he is really specifying the position of A relative to axes fixed on his ship (B).

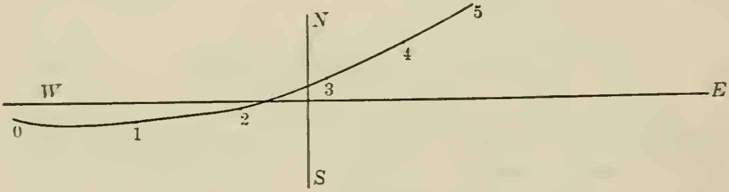
Continuing the illustration of the ship, imagine the points on lines a and b to be the positions of ships A and B respectively with respect to "land" at 12 o'clock, 1 o'clock, 2 o'clock, etc. Then these lines are the paths of the ship relative to land. The distances (west and south) of A from B

at the even hours were taken from this figure and they are recorded in the adjoining table.



Time	0	1	2	3	4	5	hours
Distance west	65	42	16	— 5	— 25	— 42	miles
Distance south	5	5	2	— 5	— 15	— 23	"

These distances have been laid off in the adjoining figure with reference to the coördinate axes *EW* and *NS*, furnishing the points 0, 1, 2, 3, etc. These points are the relative

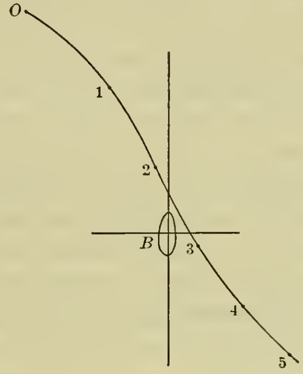


positions of *A* with respect to the meridian and parallel through *B* at the even hours, and the smooth curve through the points is the path of *A* relative to (the mentioned lines through) *B*. To an observer on ship *B* carefully estimating the position of *A* relative to his meridian and parallel, ship *A* would seem to appear to move in the path shown in the figure; that is nearly eastward for several hours and nearly northeastward from 3 to 5 o'clock.

The position of ship *A* at the even hours when referred to reference lines on ship *B* are as follows:

12 o'clock, 70 miles, 3 points off the port bow;
1 o'clock, 42 miles, 2 points off the port bow;
2 o'clock, 16 miles, 1 point off the port bow;
3 o'clock, 8 miles, 1 point abaft the starboard beam;
4 o'clock, 28 miles, broad off the starboard quarter;
5 o'clock, 48 miles, broad off the starboard quarter.

These coördinates are laid off in the adjoining figure and they determine the points 0, 1, 2, etc., the positions of *A* relative to ship *B* on the even hours. The smooth curve through these points is the path of *A* relative to ship *B*. It will be noted that the path is quite different from the path of *A* relative to the meridian and parallel through *B* (see preceding figure).



2. *Definitions.*—By velocity of a point relative to any particular body is meant the rate at which the point is passing over its path relative to that body. We regard this velocity as having a definite direction—as well as magnitude—at each instant; the direction is that of the tangent to its (relative) path at the position of the point at the instant in question. By acceleration of a point relative to a body is meant the rate at which the velocity of that point relative to the body is changing. We sometimes speak of velocity (or acceleration) of a point relative to another point; in that case certain axes of reference through the second point are understood or implied. These implied axes of reference are generally understood to be

fixed in direction relative to the earth; they are to be so understood in the following article. Thus when we speak of the velocity of a ship A with respect to another (distant) ship B (regarded as a point), we probably mean the velocity of A (regarded as a point with reference to the meridian and parallel through B (regarded as a point).

Though a terrestrial point partakes of the earth's daily rotation, its annual revolution about the sun, the motion of the sun with respect to the fixed stars, etc. (?), it is convenient and customary to speak of motions of terrestrial points with respect to the earth as "absolute motions."

3. *Relation Between Relative and Absolute Motions of a Point.*—(1) Let A and B be two points moving with respect to the earth. Then: The velocities (or accelerations) of the points relative to each other are equal and opposite; the absolute velocity (or acceleration) of A equals the vector sum of its relative velocity (or acceleration) with respect to B and the absolute velocity (or acceleration) of B. (2) Let A be a point and B a body, both moving with respect to the earth. Then the absolute velocity of A at any instant equals the vector sum of its relative velocity with respect to B and the absolute velocity of that point of B (extended if necessary) with which A happens to coincide at the instant in question. The relation between the absolute and relative accelerations of A is not so simple.

Chapter V. Some Fundamentals of Dynamics.

1. *Force.*—The word force means a push or a pull. A living thing (man for example) when pushing or pulling another thing is said to exert a force on that (other) thing; also an inanimate thing which is pushing or pulling something else is said to act and to exert a force on that (other) thing. If the thing (or agent) which exerts a force on some other thing or body is of no immediate interest, then we sometimes say that "the force acts" on that (other) body.

2. *Weight.*—In common speech the word weight is used in

at least three senses, namely, to denote (*a*) the "heft" of or earth-pull on a thing, (*b*) the amount of "stuff" or material in a thing as ascertained by weighing, and (*c*) any one of the pieces of metal used in the operation of weighing by means of a beam-scale. The third usage is never confused with either of the others, and it need not be considered in the present connection; the first two are not sharply distinguished commonly but they should be by the student of mechanics. To an engineer designing a 100-ton coal bunker, weight means earth-pull primarily; he designs for strength to withstand that pull. To a drayman engaged in transporting 100 tons of coal, weight means earth-pull, for his difficulties of hauling are due mainly to earth-pull on the coal. To the user of coal, weight of his coal pile suggests quantity of that material.

In order to avoid the double meaning of the word weight just explained, probably all modern writers on physics and many writers on allied subjects, use the word weight in the single sense of earth-pull or gravity; and some of these writers use the word mass to denote quantity of material but this word is used more often in scientific literature in another sense (see Art. 7).

3. *Quantity of Material* is stated in various ways, depending on custom or convenience and appropriateness. For example, quantity of water is generally stated in gallons or cubic feet, and sometimes in pounds or tons; quantity of earth (in construction work, say) is stated in cubic yards; quantity of steel in pounds or tons; etc. Thus, quantity of material is generally stated by volume or by weight—but quantity of cloth, for example, is stated in square (or running) yards. In either case quantity is measured by means of some property of material; in the first by its space-occupying property and in the second by its gravitating property.

4. *"Standards of Weight"* are those certain bodies (pieces of metal which the various nations have designated as standards for measurement of material by weight. We will call them "standard bodies" because they are used also as stan-

dards for other quantities as explained later (Arts. 5 and 7). Our own country has two standard bodies, a kilogram body and a pound body. These respectively are close copies of the International standard kilogram body (preserved in the International Bureau of Weights and Measures at Paris) and the Imperial standard pound body (preserved in the Office of the Exchequer at London).

5. *Units of Force.*—For many purposes it is convenient to use as unit force the earth-pull (or weight) of the standard pound (or kilogram) body. This (unit) force is called by the name of the body; that is earth-pull on a pound (body) is called a pound (force); and the earth-pull on a kilogram (body) is called a kilogram (force). Inasmuch as the earth-pull on a given body varies slightly from place to place, the pound (or kilogram) force is defined, by some, to be the earth-pull on a pound (or kilogram) body at a particular place; for example London, or any point at sea level in latitude 45°. That one of these particular pounds (or kilograms) if generally adopted, might be called the standard pound (or kilogram) force, and the earth-pull on a pound (or kilogram) body at any other place, might be called the local pound (or kilogram) force for that place.

As already stated, the word weight is used herein to mean earth-pull, and so weights are expressed in units of force.

6. *Law A.*—How does a body behave when subjected to a single force? It would seem to be easy to find the answer to this question by means of direct experiment, but it is practically impossible to provide and observe a body under the action of ony one force. A falling body is a near approach to this case, but it is under the action of two forces, the earth's pull and air resistance; we conceive of the motion as taking place under the action of a single (imaginary) force, the resultant of the two forces mentioned. Even casual observations show that a body falls with increasing velocity—that is, with acceleration. Another simple case is that of a body dragged along a level roadway; the motion takes place under the action of at least three forces, namely,—

the applied pull P (assumed horizontal), the earth-pull W on the body, and the force R exerted by the roadway. For simplicity we regard the vertical component of R to balance W, and then conceive the motion as taking place under the action of a single force, the resultant of P and the horizontal (or friction) component of R. Even casual observations show that when the pull P is greater than the friction, the velocity of the body increases; and velocity seems to increase more rapidly the greater the excess of R over friction, the resultant (F say) of P and friction.

Laboratory experiments on dragging a body, though difficult to carry out successfully, indicate that the rapidity of velocity change or acceleration varies directly with the magnitude of the resultant of the applied forces, and there is much indirect evidence showing conclusively that *when a body is subjected to two forces (or two resultants) in succession so as to make the body move in a straight line, then the accelerations in the two motions are directly proportional to the forces (or resultants)*. Or, symbolically

$$a/a' = F/F', \tag{1}$$

wherein a and a' are the accelerations corresponding to (or due to) the forces F and F' respectively.

If W denotes the weight of any body, g the acceleration due to gravity (produced by W in that body when allowed to fall), and a the acceleration produced in the same body by any force (or resultant) F, then according to (1),

$$\frac{a}{g} = \frac{F}{W}, \tag{2}$$

or as it is more commonly written

$$F = \frac{W}{g} a. \tag{3}$$

Inasmuch as the values of g are well known—at least approximately—and the weight of any body can be readily ascertained usually, it is easy to ascertain by means of (3) the value of F required to produce any given a in any particular body, or the value of a produced by any given F applied to that body.

7. *Inertia; Mass.*—Experience teaches that a body at rest is disposed or inclined, so to speak, to remain at rest indefinitely; it moves, if at all, because of the action of some other body upon it. Likewise, if a body is moving in a straight line (rectilinear motion) at constant speed, it inclines to remain in that state; any change in speed or direction of motion comes about only through the action of some other body. This reluctance or inability of a body unaided to move itself or change the amount or direction of its velocity is called inertia; and we say that all bodies are inert. In this sense of the words, all bodies have inertia or are inert in the same degree—just as all dead animals (large and small) are equally dead.

Some writers use these words in a quantitative way; thus they say that different bodies have unequal inertias or are unequally inert, meaning that different bodies require different amounts of force to produce in them any given velocity (or change of velocity) in a specified time. But more writers use the word mass in this sense, and measure the masses of different bodies in accordance with the following

Definition.—The masses of two bodies are proportional to the forces required to give them equal accelerations; that is, if m_1 and m_2 denote the masses of two bodies, and F_1 and F_2 are the forces which give them respectively equal accelerations, then

$$\frac{m_1}{m_2} = \frac{F_1}{F_2}. \tag{4}$$

Since any two bodies falling freely at the same place under the influence of only gravity have equal accelerations,

$$\frac{m_1}{m_2} = \frac{W_1}{W_2}, \tag{5}$$

that is, the masses of two bodies are proportional to their weights respectively at the same place. This relation is the basis of the practical method employed for determining masses of bodies.

A commonly used unit of mass is the mass of a pound body; this unit is called a pound (mass). (It should be noted that the word pound is used to denote several different things; thus we speak of: (*a*) one pound of copper to mention a certain amount of that material; (*b*) one pound of force, to mention a certain amount of force; (*c*) one pound of mass, to mention a certain amount of mass; and even (*d*) one pound of money to mention a certain amount of money.*

8. *Law B.—If two bodies be subjected separately to two single forces (or resultants) so that the bodies have rectilinear motion, then their accelerations will be directly proportional to the forces and inversely proportional to the masses respectively.* Or, symbolically,

$$\frac{a_1}{a_2} = \frac{F_1}{F_2} \times \frac{m_2}{m_1}, \tag{6}$$

wherein a_1 and a_2 denote the accelerations, F_1 and F_2 the forces and m_1 and m_2 the masses respectively. This law follows from law A and the definition of the ratio of masses in the preceding article. Though not independent of A, the law is important enough to deserve separate statement. Indeed law B contains more than is apparent in A, and is preferred by many writers.

It follows from equation (6) that

$$\frac{F_1}{m_1 a_1} = \frac{F_2}{m_2 a_2} = \frac{F_3}{m_3 a_3} = \text{etc.}, \tag{7}$$

where a_3 is the acceleration produced by a force F_3 in a body whose mass is m_3; hence the ratio of the force to the product of the acceleration produced and the mass is constant, that is

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* The word degree is overworked in a similar way. Thus we have degrees of temperature, of angle, of humidity, of hardness (of water); of density (of liquids). These degrees are not related, or not so closely as are the pounds, and therefore are not confused as the pounds are sometimes.

$$\frac{F}{ma} = K, \quad \text{or} \quad F = Kma, \tag{8}$$

where K denotes a constant. The value of the constant depends on the units used for F, m, and a as explained presently.

First Scheme of Units.—Any convenient units of length and time are chosen for unit of acceleration; and the mass (inertia) and the weight (earth-pull, at a specified place if desired) of any (customary) standard body as units of mass and force respectively. For example, the foot-per-second per second for acceleration, the pound (mass) for mass, and the pound force (for force). For such units $K = 1/32.2$ approximately; more exactly the numerical value of g (in feet per second per second) corresponding to the particular pound force adopted. Then equation (8) takes the form

$$F = \frac{ma}{32.2}. \tag{9}$$

Second Scheme of Units.—Any convenient unit of length and time are used; the units of force and mass are chosen so that when unit force is applied to a (free) body of unit mass, the body will have unit acceleration. This scheme makes K unity,—the express purpose of the scheme; but it requires the adoption of a new unit of force or of mass, as explained below. The equation then is

$$F = ma. \tag{10}$$

(*a*) Foot, pound (mass), second system. A force which gives a pound body an acceleration of one foot per second per second is the unit force in this system; it is called poundal. This name was proposed by Professor James Thomson of England; the unit is used in many English and American books on physics; it is rarely used outside of academic circles.

(*b*) Centimeter, gram (mass), second (or C.G.S.) system. The force which gives a gram body an acceleration of one centimeter per second per second is the unit force; it is called dyne. This unit and the name dyne and in fact the C.G.S. system were devised in 1873 by a committee of English scientists. That system has been generally adopted in all scientific circles, and is the basis of nearly all measurement in the field of electrical engineering.

(*c*) A system without name; sometimes called English (speaking) engineers'. This system is based on the foot, the second, and the pound (force). The mass of any body which under the action of a pound force moves with an acceleration of one foot per second per second is the unit of mass. This unit, though widely used in books of mechanics, is generally not named; in some it is called "engineers' unit of mass." Several special names for it have been proposed in recent years: "slug" (the first syllable of sluggish), proposed by Prof. A. M. Worthington of England, seems to be well understood in engineering educational circles of that country. The word has scarcely a foothold in our country.

9. *Non-rectilinear motion of a Body.*—The dynamics of the various sorts of this kind of motion is taken up in subsequent chapters. In large part the principles are based on the conception that bodies are made up of particles and on the following "extension" of laws A and B:

When a particle is subjected to one or more forces then in general it moves with acceleration. At each instant the resultant (R) of the forces and the acceleration (a) have the same direction: the acceleration is directly proportional to R and inversely proportional to the mass (m) of the particle. If systematic units (second scheme Art. 8) are used then

$$a = R/m \quad \text{or} \quad R = ma.$$

If F', F'', etc., denote the forces then

$$F_x' + F_x'' + \cdots = ma_x,$$

where F_x', F_x'', etc., denote the components of F', F'', etc., along any line x, and a_x denotes the component of a along that same line.

10. *Action and Reaction.*—If a body A exerts a force upon a second body B, the body B at the same time exerts upon A a force of equal magnitude in the opposite direction. One of the forces of such a pair is often called an action and the other a reaction; hence the principle may be stated in the words "to every action there corresponds an equal and contrary reaction." In spite of the importance and simplicity of this principle its true meaning has often been missed.

Chapter VI. Motion of the Center of Mass of a Body; Moment of Inertia and Radius of Gyration.

1. *Definitions.*—By center of mass of a body is meant a certain mean point whose position may be computed as follows: Let m', m'', etc., be the masses of the elementary particles of the body; (x', y', z') (x'', y'', z''), etc., their coördinates respectively; and (x, y, z) the coördinates of the mass-center; then

$$\bar{x} = \frac{m'x' + m''x'' + \cdots}{m' + m'' + \cdots}, \quad \bar{y} = \frac{m'y' + m''y'' + \cdots}{m' + m'' + \cdots},$$
$$\bar{z} = \frac{m'z' + m''z'' + \cdots}{m' + m'' + \cdots}.$$

This point coincides with the center of gravity of the body, generally conceived as being that point of the body (or of its extension) through which the resultant force of gravity on the body always acts, as the body is turned about. The center of mass is also called center of inertia because of its property stated in the following article.

For some purposes, it is convenient to classify forces exerted on a body into external and internal. An *external force* is a force exerted on the body under consideration by some other body; an *internal force* is a force exerted on a part of the body under consideration by another part.

2. *Principle of Mass-Center Motion.*—The motion of the mass-center (of a moving body) does not depend at all upon the internal forces; the mass-center moves precisely as though

all the material of the body were concentrated at the mass-center, and all the forces were applied to that dense point equal and parallel to their actual values and directions respectively. This principle holds for *any* body (not necessarily rigid) and for any kind of motion of the body; it is therefore of wide application. In general, the principle leads to three useful equations, namely,

$$R_x = M\bar{a}_x, \quad R_y = M\bar{a}_y \quad \text{and} \quad R_z = M\bar{a}_z,$$

where R_x, R_y and R_z denote the algebraic sums of the components along three rectangular axes (x, y and z) of all the external forces; $\bar{a}_x$, $\bar{a}_y$ and $\bar{a}_z$ the components of the acceleration of the mass-center along these lines, and M the mass of the body.

3. *Moment of Inertia.*—As already stated (Chap. V), when a body moves so that all points of it describe straight lines (rectilinear motion of the body), its acceleration (if any) is directly proportional to the resultant of all the forces acting on it and inversely to the mass of the body. As explained in Art. 3, Chap. VII, when a body is made to rotate about a fixed axis, its angular acceleration, if any, is directly proportional to the torque of all the (external) forces (acting on the body) about the axis of rotation and inversely proportional to the moment of inertia (defined presently) of the body about that line. Just as its mass is a measure of the reluctance of a body to take on linear acceleration, so its moment of inertia about a line is a measure of the reluctance of a body to take on angular acceleration about that line. It may be mentioned also that the kinetic energy and the angular momentum (see Chaps. VIII and IX) of a rotating body depend on the moment of inertia of the body about the axis of rotation. Thus this quantity seems to be of considerable importance in a study of rotation; it will be discussed therefore as a preliminary to such study.

Definition.—The moment of inertia of a body with respect to any line is the sum of all the products obtained by multiplying the mass of each elementary particle of the body by the square of its distance from the line. Thus if m_1, m_2, m_3, etc., be the masses of the particles, and r_1, r_2, r_3, etc., their distances respectively from the line, then

$$I = m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^2 + \cdots = \Sigma\ mr^2, \tag{1}$$

I being the symbol (commonly used) for moment of inertia. If the body under consideration is continuous, then we may write

$$I = \int dMr^2, \tag{2}$$

wherein dM denotes the mass of any elementary portion and r its distance from the line about which the moment of inertia is taken, the integration to be "extended" over the entire body.

4. By means of the foregoing formula it is easy to compute the moment of inertia of any simple geometrical solid with respect to a line which is simply related to the solid. The following are a few such cases*; M means mass of the solid:

(1) Right Parallelopiped, edges a, b and c; about a line through its center and parallel to the edge c (say),

$$I = M(a^2 + b^2)/12.$$

(2) Right Circular Cylinder, base radius r; about the axis of the cylinder

$$I = \frac{1}{2} Mr^2.$$

(3) Right Circular Cone, base radius r; about the axis of the cone,

$$I = 3Mr^2/10.$$

(4) Ellipsoid, semi-axes a, b and c; about the axis $2c$ (say)

$$I = M(a^2 + b^2)/5.$$

5. It is obvious from equations (1) or (2) that a unit moment of inertia is one "dimension" in mass and two in

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* For other cases see tables of moment of inertia in any Engineer's "Pocket Book" or Book on Mechanics.

length; hence the magnitude of a unit moment of inertia depends on the units of mass and distance used. Corresponding to the pound (mass) and foot (length), the unit moment of inertia is called pound-foot^2; corresponding to the gram and centimeter, the unit moment of inertia is the gram-centimeter^2. (These compound names were chosen on the same basis as were the compounds foot-pound, acre-foot, etc.)

6. *Radius of Gyration.*—The radius of gyration of a body with respect to any particular line is such a length which when squared and multiplied by the mass of the body gives a result equal to the moment of inertia of the body about the line. Or, symbolically, if k denotes this radius of gyration then

$$k^2M = I, \text{ or } k = \sqrt{I/M}. \qquad (3)$$

This form (k^2M) for I is of practical convenience in some connections.

The radius of gyration of a body with respect to a certain line may be regarded also as follows: Imagine all the material of the body concentrated into a point so located that the moment of inertia of this material point about the line in question equals the moment of inertia of the body about that line; then the distance between the line and the point equals the radius of gyration of the body about that line. The material point is called the "center of gyration" of the body for the particular line by some writers.

The radius of gyration of a homogeneous body with respect to any particular line may be regarded still differently. Its square equals the mean of the squares of the distances of all the equal elementary parts of the body from that line. Or symbolically

$$k^2 = (r_1^2 + r_2^2 + r_3^2 + \cdots) \div n,$$

where n is the (infinite) number of elementary parts. Evidently the value of k lies between the least and the greatest distance r. Thus this conception of radius of gyration affords a basis for roughly estimating the value of this radius for a given body.

7. *Parallel Axes Theorems.*—There is a very simple relation between the moments of inertia—and the radii of gyration—of a body with respect to parallel lines, one of which contains the mass-center of the body; and by means of these relations, one can simplify many calculations of moment of inertia, and generally avoid use of equation (2). It may be stated thus: The moment of inertia of a body with respect to any line equals its moment of inertia with respect to a parallel line through the mass-center plus the product of its mass and the square of the distance between the lines; or in symbols

$$I = I_0 + Md^2, \tag{4}$$

wherein I and I_0 denote the moments of inertia respectively, M the mass of the body, and d the distance between the lines.

The tables (already mentioned) of moments of inertia commonly give the moments of inertia of each simple geometric solid about several lines through the mass-center. These moments of inertia may be "transferred" to parallel axes by means of equation (4). For example, the moment of inertia of a cylinder with respect to its axis is $\frac{1}{2}Mr^2$ (see Art. 4); with respect to an element of its curved surface the moment of inertia is

$$\tfrac{1}{2}Mr^2 + Mr^2 = 3Mr^2/2.$$

For radii of gyration the parallel axes theorem is

$$k^2 = k_0{}^2 + d^2, \tag{5}$$

wherein k is the radius of gyration with respect to any line, k_0 that for a parallel line through the mass-center, and d is the distance between the lines. It follows from (5) that

$$k = d\sqrt{1 + (k_0/d)^2}.$$

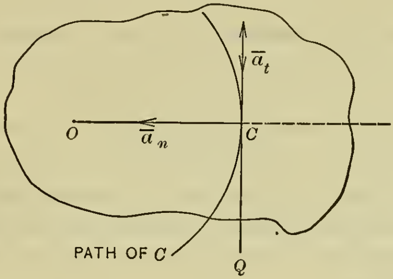
Hence k is always greater than d; that is, radius of gyration of a body with respect to a line is always greater than the distance from the line to the mass-center. But if the greatest dimension of the body in a direction perpendicular to the line (about which radius of gyration is being considered) is small in comparison with d, then $(k_0/d)^2$ is small compared to 1, and k equals d approximately. For example, the radius of gyration of a sphere of radius r about a line $10r$ from its center is $10.02r$.

Chapter VII. Motion of a Rigid Body. (Continued from Chapter III.)

1. *Translation* (See Art. 1, Chap. III).—At each instant of the motion, or for each position of the body, the resultant (R) of all the external forces applied to the body is a single force. If M and a denote the mass and acceleration of the body, then for each instant

$$R = Ma;$$

R and a have the same direction. The algebraic sum of the components of all the forces along any line perpendicular to the direction of R and a equals zero. The line of action of R passes through the mass-center of the body; it follows that R, and hence the forces, have no torque about any line passing through the mass-center.



2. *Rotation about a Fixed Axis* (See Arts. 2 to 5, Chap. III).—Let the figure represent the section of a body rotating about a fixed axis, the section being perpendicular to the axis of rotation and containing the mass-center; let C be the mass-center, O the center of rotation (where the axis of rotation cuts the section); $\bar{r}$ denotes OC, ω and α respectively the

angular velocity and acceleration of the body, $\bar{v}$ and $\bar{a}$ respectively the (linear) velocity and acceleration of the mass-center, $\bar{a}_n$ and $\bar{a}_t$ the normal and tangential components of $\bar{a}$. Imagine each (external)force acting on the body (not omitting the reaction of the axle, shaft, or bearings) resolved into three (rectangular) components parallel to the ''tangent'' CQ, the normal OC, and the axis of rotation; and let ΣF_t, ΣF_n, and ΣF_a respectively denote the sums of these tangential, normal, and axial components. Then it follows from the principle of mass-center motion (Art. 2 Chap. VI) that

$$\Sigma F_t = M\bar{a}_t,\ \Sigma F_n = M\bar{a}_n \text{ and } \Sigma F_a = 0. \qquad (1, 2, \text{and } 3).$$

We recall (see Art. 5, Chap. III) that $\bar{a}_t = \bar{r}\alpha$ and $\bar{a}_n = \bar{v}^2/\bar{r} = \bar{r}\omega^2$.

Two special cases may be noted: (*a*) If the angular velocity is constant, then ΣF_t, as well as $\Sigma F_a, = 0$; (*b*) if the mass-center is in the axis of rotation, then the algebraic sum of the components of all the external forces along any line equals zero.

3. *The prime equation* for a motion of rotation is

$$\alpha = T/I, \quad \text{or} \quad T = I\alpha, \qquad (4)$$

the latter being the more common form. Here α means the angular acceleration of the rotating body at any instant, T the torque (for that instant) of all the external forces (including axle or shaft reaction) acting on the body, and I the moment of inertia of the body with respect to (or ''about'') the axis of rotation.

4. The foregoing equations (1, 2, 3, and 4) generally suffice for the more simple problems on motions of rotation. In general, two additional (moment) equations are available; but the equations are complicated. In certain special cases (bodies more or less symmetrical) the equations are simple. One such case (common among rotating machine parts) is this: the body is homogeneous and has a plane of symmetry perpendicular to the axis of rotation. In this case, *the torque of all the forces acting on the rotating body about any*

line in the plane of symmetry equals zero. On the basis of this fact we may write (in addition to equations 1, 2, 3 and 4)

$$T_1 = 0 \text{ and } T_2 = 0, \qquad (5),\ (6)$$

where T_1 and T_2 denote the torques of all the external forces about two non-parallel lines in the plane of symmetry.

5. *Plane* (*or Two-dimensional*) *Motion* (See Art. 6, Chap. III).—In accordance with the principle of mass-center motion,

$$\Sigma F_x = M\bar{a}_x,\ \Sigma F_y = M\bar{a}_y,\ \Sigma F_z = 0; \qquad (1, 2, 3)$$

where M denotes mass of the body, $\bar{a}_x$ and $\bar{a}_y$ the components of the acceleration of the mass-center along two lines at right angles to each other in the plane of the motion, ΣF_x and ΣF_y and ΣF_z the algebraic sums of the components of all the external forces acting on the body along these two lines and one perpendicular to the plane of the motion.

Let $\bar{T}$ denote the torque of all the external forces, acting on the body, about a line through its mass-center and perpendicular to the plane of the motion, $\bar{I}$ and $\bar{k}$ the moment of inertia and radius of gyration of the body with respect to that line, M the mass of the body, and a the angular acceleration of the body at the instant for which $\bar{T}$ is the torque; then

$$\bar{T} = \bar{I}a = M\bar{k}^2a. \qquad (4)$$

This equation is entirely independent of the motion of the mass-center; thus the rotation of the body about the mass-center might be determined just as though that point were at rest. Moreover, equations (1), (2) and (3), which determine the motion of the mass-center, do not involve the turning of the body; thus there is complete independence between the motion of the mass-center and the rotation of the body about that point.

In general, two "torque equations" in addition to equation (4) are available for analyzing this kind of motion. These equations are not simple except in certain special cases, as for example: If the body is homogeneous and has a plane of symmetry parallel to the plane of the motion; in this case the torque of all the external forces about any line in the plane of symmetry is zero.

6. *Solid* (*or Three-dimensional*) *Motion* (See Art. 8, Chap. III).—Motion of the mass-center and rotation about that point are independent; these motions may be treated separately. The first as though all the material of the body were concentrated at the mass-center and the forces applied there (see Art. 2, Chap. VI); the second as though the body were fixed (pivoted) at the mass-center. The equations for determining this rotation are not simple.

Chap. VIII. Work, Energy, Power.

1. *Work.*—When a force is applied to a body and its point of application moves (as the result of this action or other forces) then, in general, the force—and also the agent which exerts that force—is said to do work on the body. "Other things being the same," the greater the force, the greater the work; and the greater the displacement of its point of application, the greater the work.

The following are some rules for computing precisely the amount of work:

(*a*) The force F is constant in amount and direction and its point of application moves along the line of action of the force. For any particular displacements of the point of application, the amount of work is the product of the force and the displacement; or symbolically Fs.

(*b*) If the force is constant in amount and direction and the displacement of its point of application is straight but inclined to the force, then the amount of work done by the force during this displacement is $(F\cos\theta)s$, where θ is the acute angle between the force and the line of displacement. $F\cos\theta$ is the component of F along the line of the displacement, and it is sometimes called the "working component" of F. Using that term, we may state the foregoing formula thus:

$$\text{Working component} \times \text{displacement}.$$

The formula can be written $F(s\cos\theta)$; and since the product $s\cos\theta$ is the projection of the displacement on the line of action of the force, the formula can be rendered thus:

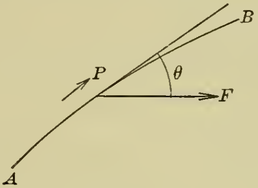
force × projected displacement.

(*c*) The force varies in magnitude or direction and the motion of its point of application is straight or curved (general case). Let AB (see figure) be the path of the moving point of application P (on a body not shown) of a force F, and θ the angle between F and the tangent at P. Then $F\cos\theta$ is the working component of the force, and the work done by F during the displacement from A to B is

$$\int F\cos\theta ds$$

the integration "extending" over the arc AB.

2. The foregoing formulas imply that the unit work equals the work done by a unit force during a unit displacement of the point of application along the line of action of the force. For example,—one pound (force) acting through one foot, one dyne acting through one centimeter, etc. The dyne-centimeter is called erg more commonly; for a larger (practical) unit 10^7 ergs have been chosen, and this unit is called a joule. The following also are in use in certain fields:



horse-power-hour (=1,980,000 foot-pounds),

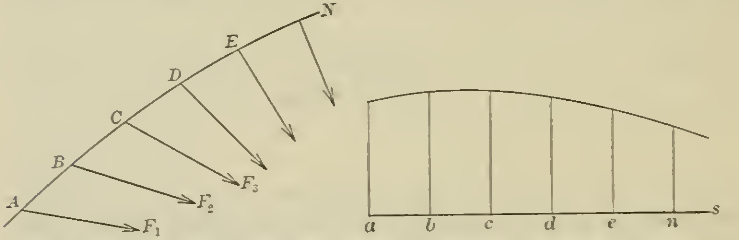
the amount of work done by an agent in one hour when working at the rate of one horse-power (see Art. 9);

kilowatt-hour (=3,600,000 joules),

the amount of work done by an agent in one hour when working at the rate of one kilowatt (see Art. 9).

3. When the works of several forces are under discussion, it may be convenient to give signs to their works according to some rule; the following is the usual rule. The sign is positive or negative according as the working component acts in or opposite to the direction of the motion of the point of application of the force. For example, during the motion of a railroad train, the first car is pulled forward by the locomotive and backward by the second car, ordinarily; the work of the first pull is positive and that of the second is negative. And while a thrown ball is rising the work being done on it by gravity is negative; while descending, gravity is doing positive work. Forces are sometimes called efforts or resistances according as they are doing positive or negative work.

4. *Work Diagram.*—Let F be a varying force whose point of application P moves along the line AN (see figure) the body is not shown), and F_1, F_2, etc., the values and directions



of F for the particular positions of the point of application indicated. Also let $abc \cdots n$ be the path of P straightened out, a, b, c, etc., corresponding precisely to A, B, C, etc. Now imagine the ordinates erected at a, b, c, etc., to represent, according to any convenient scale, the working components $F_1 \cos\theta_1$, $F_2 \cos\theta_2$, etc., and a smooth curve drawn through the (free) ends of the ordinates. The average ordinate for any portion of the curve represents the (space) average working-force for the corresponding displacement; and the product of this average and the displacement is the work done by the force F during that displacement.

5. *Energy.*—When the state or condition of a body is such

that it can (exert force and) do work, then it is said to have or possess energy. For example, ocean winds can "if given a chance," exert force and do work on sailing vessel; the winds (moving air) therefore possess energy. A compressed or stretched spring can be released in such a way that it would pull or push a body and do work; a compressed or stretched spring possesses energy therefore.

The amount of energy possessed by a body at any instant is the amount of work which it can do while its state changes from that of the instant to an assumed standard state (explained presently). Therefore amounts of energy are expressed in units of work (see Art. 2).

6. Kinetic energy is energy which a moving body has by virtue of its velocity. The amount of kinetic energy which a moving particle has is the amount of work which it can do in "giving up" all its velocity; thus the standard state is one of zero velocity. It can be shown that the kinetic energy of a particle is proportional to its mass and velocity square; if m and v denote its mass and velocity respectively then the common formula is $\frac{1}{2}mv^2$ or $\frac{1}{2}(w/g)v^2$, use of certain units being understood.

The kinetic energy of a moving body, conceived as consisting of particles, is the sum of the kinetic energies of the particles.

(*a*) The kinetic energy of a rigid body having a motion of translation is given by

$$\tfrac{1}{2}Mv^2 = \tfrac{1}{2}\frac{W}{g}v^2,$$

where M, v, and W are its mass, velocity, and weight respectively.

(*b*) The kinetic energy of a body rotating about a fixed axis is given by

$$\tfrac{1}{2}I\omega^2 = \tfrac{1}{2}Mk^2\omega^2 = \tfrac{1}{2}(W/g)k^2\omega^2;$$

I denotes moment of inertia of the body with respect to the axis of rotation, k the radius of gyration with respect to that axis, and ω its angular velocity ($=2\pi n$ where n is revolutions per unit time).

(c) The kinetic energy of a body having a plane motion (like a rolling wheel), combined translation and rotation, (Art. 6, Chap. III) is given by

$$\tfrac{1}{2}Mv_0^2 + \tfrac{1}{2}I_0\omega^2,$$

where v_0 is the velocity of the mass-center, I_0 the moment of inertia of the body about a line through the mass-center and perpendicular to the plane of the motion, and ω the angular velocity of the body. The portions $\frac{1}{2}Mv_0^2$ and $\frac{1}{2}I_0\omega^2$ of the kinetic energy are sometimes called translational and rotational components respectively.

7. *Potential Energy.*—As already mentioned, a strained spring has energy. For any given spring, the amount of energy depends largely if not wholly on the amount of the strain (the change from natural form and shape). The energy seems to be associated with the relative positions of the particles of the spring. A body elevated above the surface of the earth can do work by descending; thus it has energy in an elevated position. Energy of a body (or system) which is due to configuration or position of the body or of its parts is called potential energy. The amount of potential energy possessed by a body in any particular position or configuration is the work which the body can do in passing to the (assumed) standard state. In the case of a spring, the standard state is its unstrained or natural state; for an elevated body, the standard state is its lowest possible position (at surface of the earth generally).

8. *Other Forms of Energy.*—Kinetic and potential energy are called mechanical to distinguish these forms from others not obviously kinetic or potential. These other forms are thermal, chemical, electrical. They are (large) subjects of special study and will not be discussed here.

9. *Power.*—This word has been used in various senses in technical literature. It was once much used in the sense of force; now rarely so. At present it is often used in the

sense of energy; but the best usage limits it to mean rate at which work is being (or can be) done, or energy is being (or can be) delivered or converted by any agent, machine, etc. Thus we speak of the power of a motor, the power of a locomotive, etc.

The following are the most commonly used units of power. English and American horse-power = 550 foot-pounds per second

= 33,000 foot-pounds per minute;

Continental horse-power = 75 kilogram-meters per second

= 4,500 kilogram-meters per minute:

Watt = 1 joule (10 ergs) per second; and
Kilowatt = 1,000 watts = 1,000 joules per second.

The power of an agent which does work by means of a single force can be computed as follows: Let F_t be the working component of the force (along the line of motion of its point of application), and v the velocity of that point; then

$$P = F_t \cdot v.$$

If the agent does work by means of forces whose points of application are rotating about a common axis, then the power of the agent at any instant is $T\omega$, where T is the torque of the forces about the line at that instant, and ω the angular velocity of rotation then.

9. *Principles of Work and Kinetic Energy.*—(1) During any displacement of a body (or collection of bodies) not rigid necessarily, the sum total of work done upon it by all the forces (external and internal) equals its gain in kinetic energy. (It is to be understood that signs must be given to the works done by the several forces in accordance with the rule in Art. 3; and sum means algebraic sum.) If the sum total is positive then there is a real increase in kinetic energy; if negative, then a decrease. If forces be classed into efforts and resistances as explained in Art. 3, then the foregoing principle might be stated (briefly) thus:

work of the efforts — work of the resistances
equals gain in kinetic energy;

all works being regarded as positive.

(2) If the body under consideration is a rigid one, then the internal forces do no work; hence during any displacement of a rigid body the sum total work done upon it by the external forces equals the gain in the kinetic energy of the body.

10. *Conservation of Energy.*—If a body or system of bodies is isolated so that it neither receives or gives out energy, then its total store of energy, all forms included, remains constant; there may be a transfer of energy from one part of the body or system to another but the total gain or loss in one part is exactly equal to the loss or gain in the remainder; transformation of all or of a portion of the energy from one kind to another may take place but it does not change the total amount.

Chapter IX. Momentum and Impulse.

1. *(Linear) Momentum.*—By momentum of a moving particle is meant the product of the mass and velocity of the particle. Momentum of a particle is regarded as having direction, that of the velocity of the particle; thus momentum is a vector quantity. By momentum of a collection of particles, constituting a body (not rigid necessarily), is meant the vector sum of the momentums of the particles. Thus in the simple case of a collection constituting a rigid body and having a motion of translation, the vector sum equals the arithmetic sum

$$m_1v + m_2v + \cdots = Mv,$$

where m_1, m_2, etc., are the masses of the particles respectively, v their common velocity and M the mass of the entire body.

Since it is a vector quantity, the momentum of a body can be resolved into components, like any other vector quantity. The component of the momentum of a body along any line—the other component being perpendicular to the line—equals the product of the mass of the body and the component of the velocity of the mass-center of the body along that line.

According to the principle of mass-center motion (Art. 2, Chap. VI),

$$F_x' + F_x'' + \cdots = M\bar{a}_x,$$

where F'_x, F_x'', etc., are the x components of the external forces acting on any body at any instant; $\bar{a}_x$ is the x component of the acceleration of the mass-center at that instant, and M means mass of the body as above. Since $\bar{a}_x = d\bar{v}_x/dt$, where $\bar{v}_x$ is the component of the velocity of the mass-center,

$$F_x' + F_x'' + \cdots = d(M\bar{v}_x)/dt. \tag{1}$$

That is, the algebraic sum of the components (along any line) of all the external forces acting on a body at any instant equals the rate at which component of the momentum of the body along that line is changing then. If there are no external forces acting on the body, then the component of the momentum along any and every line is constant; this is the principle of conservation of momentum.

2. (*Linear*) *Impulse.*—If the magnitude and direction of a force are constant for any interval of time, then the product of the magnitude of the force and the interval is called the impulse of the force for that interval. If the magnitude varies, then the impulse for any interval equals the sum of the impulses for all the elementary portions of time which make up the interval; that is, impulse is

$$\int_{t_1}^{t_2} Fdt.$$

where F = the varying force and $t_2 - t_1$ is the interval. If the direction of the force varies, we regard the impulse for any elementary portion of time as a vector quantity having the direction of the force, and then in principle we add (vectorially) the elementary impulses for all the portions of time which make up the interval. That is to say, we integrate Fdt vectorially, arriving at a definite vector quantity.

The impulse of a force can be resolved into components. The component of the impulse of a force along any line equals the impulse of the component of the force along that line. Thus if F_x means the component of a force F along a line x, then the x-component of the impulse of the force for any interval $t_2 - t_1$ is

$$\int_{t_1}^{t_2} F_x dt.$$

Integration of eq. (1) gives

$$\int_{t_1}^{t_2} F_x' dt + \int_{t_1}^{t_2} F_x'' dt + \cdots = M\bar{v}_x'' - M\bar{v}_x', \qquad (2)$$

where $\bar{v}_x'$ and $\bar{v}_x''$ mean the x components of the velocity of the mass-center of the body at times t_1 and t_2 respectively. Equation (2) means that the algebraic sum of the components of the impulses of all the external forces acting on a body for any interval of time equals the increment in the component of the momentum of the body for that same interval.

3. *Angular Momentum.*—The (linear) momentum of a moving particle is a vector quantity, as explained in Art. 1; the magnitude of the momentum is *mv*, and the direction is that of the velocity. We go farther now and assign position to the momentum and to the momentum-vector. The position, or position-line, of the momentum of a particle is the line through the particle in the direction of the velocity. Thus the linear momentum of a particle is a "localized" vector quantity—like a concentrated force, which has magnitude, direction and a definite position, or line of action as it is more commonly called.

Angular momentum of a moving particle about a line means the moment of its (linear) momentum about that line; that is the product of the component of the momentum perpendicular to the line—the other being parallel to the line—and the distance between the perpendicular component and the line. (Compare definition of moment of a force about a line.) By angular momentum of a collection of particles (constituting a body) about any line is meant the algebraic sum of the angular momentums of the particles about that line. In the simple case of a body rotating about a fixed axis this sum is

$$m_1v_1r_1 + m_2v_2r_2 + \cdots = I\omega.$$

Here m_1, m_2, etc., denote the masses of the particles; v_1, v_2, etc., their velocities respectively; r_1, r_2, etc., their distances from the axis of rotation; I the moment of inertia of the body about that axis; and ω the angular velocity of the body.

It could be shown that the torque at any instant of all the external forces acting on any body about any particular line equals the rate at which the angular momentum of the body about that line is changing then. If there are no external forces acting on the body, then the angular momentum of the body about each and every line is constant; this is the principle of conservation of angular momentum.

4. *Angular Impulse.*—If the line of action of a force is fixed in position then the angular impulse of that force for any interval about any line is the moment about that line of the impulse of the force for the interval. The moment of an impulse is computed just like moment of a force or angular momentum; that is, we resolve the impulse into two components, one parallel and one perpendicular to the line and then we take the product of the perpendicular component and the distance from it to the line. If the line of action of the force changes, then the angular impulse of the force about any line for any interval is the algebraic sum of its angular impulses for all the elementary portions of time which comprise the interval. Thus let $F =$ the force, $t_2 - t_1 =$ the interval, $\theta =$ the angle between the line of action of F and the line, and $p =$ the perpendicular distance between the two lines. Then the angular impulse is

$$\int_{t_1}^{t_2} Fdt \cdot \sin\theta \cdot p = \int_{t_1}^{t_2} F \sin\theta \cdot pdt.$$

Since $F \sin \theta \cdot p =$ the torque of the force about the line in question, the angular impulse of the force may also be regarded as the time-integral of the torgue of the force. Or, if $T =$ the torque of the force about the line at any instant, then the angular momentum for the interval equals integral of $T\,dt$ over the interval $t_2 - t_1$.

It can be shown that the algebraic sum of the angular impulses of all the external forces acting on a body, about any line and for any interval of time, equals the increment in the angular momentum of the body about that line during the interval.

FORM OF SYLLABUS PROPOSED BY WILLIAM KENT. DYNAMICS.

Chapter 1. Definitions—Units.

Dynamics—the mechanics of bodies in motion.

Elementary quantities—matter, force, space, time.

Matter, properties of—bulk. volume, density, shape, weight, inertia (inertness), solid. liquid, gaseous, center of gravity.

Motion, velocity, direction, translation, rectilinear, curvilinear, rotative.

Uniform, uniformly accelerated or retarded, acceleration retarded by friction.

Relative motion—Motion of center of gravity.

Force—Push or Pull—Cause of motion or change of motion. Standard unit of force = earth-pull on 1 lb. matter at the standard locality.

Chapter 2. Action of Force on Bodies in Motion.

Resultant of two or more forces acting at a point = single force.

Uniform motion, force = frictional or other resistance.

Uniformly accelerated motion—constant force, friction negligible.

Motion variable, due to variations in force or in friction.

Chapter 3. Discussion of Uniform Motion.

Chapter 4. Discussion of Uniformly Accelerated Motion—Rectilinear.

Problem. F lbs. force acts on W lbs. matter T seconds—what are the results?

Fundamental, from experiment, $V = FTg/W$ (1)
$S = \frac{1}{2}FT^2g/W$ (2)
Derived from fundamental, energy, work, $FS = \frac{1}{2}MV^2$ (3)
Momentum, $MV = FT$
Impulse (4)
Acceleration, $A = V/T$,
$F = MA$ (5)
Velocity of falling body $V = \sqrt{2gH}$ (6)
Power FS/T

Wherever W appears in the equation, it means weight in pounds, and means both the quantity of matter and the earth-pull at the standard locality, these being the same numerically.

Wherever M appears, it is merely a letter substituted for the quotient

$$\frac{W}{32.1740}.$$

Chapter 5. Rotation about Fixed Axis—Moment of Inertia.

Chapter 6. Frictional Resistance.

Explanation of Chapter 4 in Kent's proposed syllabus.

Problem.—Two 50-lb. weights are balanced on an Atwood machine, or, a boat weighing 100 lbs. is at rest in a still pond. Apply a force of 1 lb. by means of a string for 4 seconds in the direction of one of the cords supporting the weights, or of the string towing the boat. Assuming no friction, what are the results? The data are: $W = 100$, $F = 1$, $T = 4$.

Experiment would give the following figures:

At end of each second $T =$	1	2	3	4
Total distance S ft.	0.161	0.644	1.449	2.576
Distance each second	0.161	0.483	0.805	1.127
			Total	2.576

The velocity at the end of each second may be computed from the distance thus:

The distance traversed each second equals the mean velocity in ft. per sec. during that second, or

$$s = \frac{v_1 + v_2}{2},$$

v being the velocity at the beginning and v_2 at the end of the second.

$$v_1 + v_2 = 2s. \quad v_2 = 2s - v_1$$

$T =$	1	2	3	4
$2s =$	0.322	0.966	1.610	2.254
$v_1 =$	0.	.322	.644	.966
$V = v_2 =$	0.322	0.644	0.966	1.288
Difference $v_2 - v_1 =$		0.322	0.322	0.322

We call this difference, or the increase in velocity during each second, the acceleration, and in cases like the problem, with a given body and a constant force, and no retardation by friction,

(1) The velocity is directly proportional to the time (uniform acceleration).

By repeating the experiments on the Atwood machine, or on the boat, with different forces and different weights we find the following:

(2) The weight being constant the velocity at the end of any given time is proportional to the force.

(3) The force being constant the velocity at the end of any given time is inversely proportional to the weight.

These three statements may be combined into one as follows:

In uniformly accelerated motion the velocity is directly proportional to the force and to the time, and inversely proportional to the quantity of matter, or, in algebraic form,

$$V \propto \frac{FT}{W}.$$

Taking any one of the values of v in the above example and the corresponding time, say at the end of the 4th second, $V = 1.288$, $F = 1$, $W = 100$, $T = 4$, we obtain

$$1.288 \propto \frac{1 \times 4}{100}$$

or $128.8 \propto 4$, whence we find that the constant required to convert the sign $\propto$ into $=$ is $128.8 \div 4 = 32.2 = g$ and we have

$$V = FTg/W \tag{1}$$

Considering the distances s obtained in the experiment, viz., 0.161; 0.644; 1.499; 2.576, it is found that they are in the ratios 1, 4, 9, 16, or as the squares of 1, 2, 3, 4. Hence we conclude that with force and weight constant the distance traversed is proportional to the square of the time, and we may write

$$S = \tfrac{1}{2} FT^2g/W \tag{2}$$

The same results may be obtained directly from (1) by substituting for V its value $2S/T$ (which relation may be found from the values of V and S in the example).

Equations (1) and (2) are fundamental general equations, derived directly from experiment. The value of g (in English measure) when the unit of force is defined as the force with which gravity attracts one pound of matter at or near 45 deg. sea level, is 32.1740. This figure may be considered either as an abstract number, as a distance (twice the distance that a body will fall in one second at the standard locality), as a velocity (the velocity a body requires in falling one second) or as the acceleration due to gravity, in ft. per sec. per sec., but whatever it may be called, its function in equations (1) and (2) is that of an abstract number, a constant found by experiment.

It may be observed that the attraction of gravitation or the acceleration due to gravity does not enter into the problem considered, for the earth-pull of one of the 50 lb. weights is balanced by that of the other, and that of the 100 lb. boat is balanced by the upward push of the water in the pond. The experiments would give the same results at any latitude or elevation on the earth's surface, or on the moon.

The work done, or the energy stored, in moving bodies is the product of the force into the distance through which it acts, or *FS*, or at the end of 4 seconds $1 \times 2.576 = 2.576$ ft. lbs. From equation (1) $F = WV/Tg$ and substituting the value in equation (2) and canceling, we derive

$$FS = \frac{1}{2}\frac{WV^2}{g} = \frac{1}{2}\frac{100 \times 1.288 \times 1.288}{32.2} = 2.576.$$

Work done = kinetic energy.

Momentum is a name given to the product WV/g.

Impulse is a name given to the product *FT*, and from equation (1) $V = FTg/W$ it appears that $FT = WV/g$.

Acceleration is a name given to the quotient $V/T = A$, and from equation (1) $A = V/T = Fg/W$.

In the case of a body falling at lat. 45 deg. at the sea level $F = W$ and $A = g$.

Power is the rate at which work is done FS/T or $\frac{1}{2}WV^2/Tg$.

$M = W/g$. Whenever the quotient W/g appears in an equation in dynamics it may be replaced by the letter *M*, and it may be called "mass," if it is understood that $M = W/g$; but it must be remembered that the same word "mass" is used in works on physics as synonomous with weight (quantity of matter) in pounds, and in some works on mechanics as meaning quantity of matter in a new unit, unknown in engineering or in commerce, the "slug" or "gee" pound. On account of the variety of definitions, it may be well to avoid the use of "mass," except in the generally understood sense of an indefinite quantity of matter, such as body, lump or pile. It may be used in the C.G.S. system, however, where there is no ambiguity, to mean quantity of matter in grams.

Substituting *M* for W/g in the above equations, we have

$$(1)\quad V=\frac{FT}{M},\qquad (2)\quad S=\frac{1}{2}\,\frac{FT^2}{M},$$

$$(3)\ FS=\tfrac{1}{2}MV^2,\quad (4)\ FT=MV.$$

Falling Bodies.—If $F=W$ and $S=H$, the height of fall, equation (2) gives

$$S=H=\frac{V^2}{2g},$$

whence

$$V=\sqrt{2gH}.$$

EXTRACTS FROM TWENTY TEXT BOOKS ON MECHANICS SHOWING ESPECIALLY EACH AUTHOR'S USE OF THE WORDS WEIGHT AND MASS AND HIS MATHEMATICAL FORMS OF SOME DYNAMICAL PRINCIPLES.

The extracts are more or less brief and disjointed and may not reflect the author's views correctly in every case; likewise the summary (page 310) may not be absolutely correct although it was the intention to make it so.

The following is a list of the authors: the last two (foreign) are included because they have been referred to frequently in the present connection. Church, Dadourian, Dubois, Franklin & MacNutt, Fuller & Johnson, Hancock, Hoskins, Huntington, Lanza, Martin, Maurer, Merriman, Slocum, Smith & Longley, Wood, Woodward, Wright, Ziwet and Field, Perry, and Rankine.

Church—Mechanics of Engineering.

Page 2. *Mass* is the quantity of matter in a body. The masses of several bodies being proportional to their weights at the same locality on the earth's surface, in physics the weight is taken as the mass, but in practical engineering another mode is used for measuring it (as explained in a subsequent chapter), viz.: the mass of a body is equal to the weight divided by the acceleration of gravity in the locality where the weight is taken, or symbolically, $M=G/g$. This quotient is a constant quantity, as it should be, since the mass of a body is invariable wherever the body is carried.

Page 53. Since the quotient G/g is invariable, wherever the body be moved on the earth's surface (G and g changing in the same ratio), it will be used as the measure of the mass M or the quantity of matter in the body. In this way it will frequently happen that the quantities G and g will appear in problems where the weight of the body, *i. e.*, the force of the earth's attraction upon it, and the acceleration of gravity have no direct connection with the circumstances. No name will be given to the unit of mass, it being always understood that the fraction G/g will be put for M (in $P = Mp$) before any numerical substitution is made.

Page 66. The product of a mass and its velocity is sometimes called momentum; page 137, kinetic energy $= Mv^2/2$; page 91 moment of inertia $= \int dMr^2$.

Page 76. *Notes and Examples.*—The engineer measures the mass of a body (in case a problem connected with its motion is under treatment) by the fraction, weight. Accel. of gravity, or $G \div g$. This is not scientific, but is so firmly rooted in engineering practice that no different measure can well supplant it. It seems to imply that the amount of matter in a body depends on the existence of the attraction of gravitation; whereas, of course, such is not the case. In the phrase force $=$ mass $\times$ accel., or $P = Mp$ the word mass is simply a name given to the fraction $G \div g$, the origin of which is as follows.

Dadourian—Analytical Mechanics.

Page 108. The British unit of force is the pound, which we have already defined (76) as the weight, in London, of a body which has a mass of about 453.6 gm. The weight of a body is the force with which it is attracted towards the center of the earth. Therefore if m denotes the mass of a body and g the magnitude of the acceleration which the gravitational attraction of the earth imparts to bodies, the force equation gives us

$$W = mg$$

Page 239. The vector magnitude mv is called momentum; page 187, kinetic energy of a particle $= mv^2/2$; page 152, $I = \int r^2 dm$.

Dubois—The Mechanics of Engineering, Vol. I.

Page 171. Thus if the mass of a translating body is m lbs. and the acceleration of the center of mass is f, we have for the force, if f is taken in feet per second per second,

$$F = mf \text{ poundals.}$$

But since at any locality where the acceleration of gravity is g the weight of one pound is g poundals, if we take this as the unit of force we have

$$F = mf/g \text{ pounds.}$$

Page 172. The product of the mass of a particle and its velocity is called its momentum; page 272, kinetic energy of a particle $= mv^2/2$; page 31, moment of inertia $= mr^2$.

Franklin and MacNutt—The Elements of Mechanics.

Page 71. *Dynamic Units of Force.*—Having agreed to measure a force in terms of its effect in changing the velocity of a particle, we may choose as our unit of force that force which, acting as an unbalanced force on unit mass, will produce unit velocity in unit time (unit acceleration). Thus the dyne is that force which acting for one second as an unbalanced force on a one-gram particle, will produce a velocity of one centimeter per second (an acceleration of one centimeter per second per second); and the poundal is that force which, acting for one second as an unbalanced force on a one-pound particle, will produce a velocity of one foot per second (an acceleration of one foot per second per second). The dyne is the C.G.S. unit of force and it is much used; the poundal is seldom used.

Having adopted as our unit of force that force which will produce unit acceleration of unit mass, it is evident, from Newton's second law, that

$$F = ma, \tag{3}$$

in which F is the value of an unbalanced force in dynes (or poundals), m is the mass of particle in grams (or pounds), and a is the acceleration in centimeters per second per second (or feet per second per second).

Weight. Gravitational Units of Force.—Let g be the acceleration of a freely falling body produced by an unbalanced pull of the earth; let m be the mass of the body, and let W be the force, expressed in dynamic units, with which the earth pulls the body; then, according to equation (3) we have

$$W = mg, \tag{4}$$

in which W is the weight of the body in dynes (or poundals), m is its mass in grams (or pounds), and g is the acceleration due to gravity expressed in centimeters per second per second (or in feet per second per second). The value of g is about 980 centimeters per second per second (or 32 feet per second per second) so that, according to equation (4), the weight of a gram is about 980 dynes, and the weight of a pound is about 32 poundals.

The most convenient unit of force, for many purposes, is the force with which the earth pulls the unit mass. The force with which the earth pulls one gram is called the gram-weight, and the force with which the earth pulls the pound is called the pound-weight. Thus we may speak of 5,000 pounds weight meaning the force with which the earth pulls a mass of 5,000 pounds.

Page 72. It is often desirable, in discussing practical problems, to consider the relation between force, mass, and acceleration when forces are expressed in pound-weight, mass in pounds, and acceleration in feet per second per second. In this case equation (3) becomes

$$F = ma/32. \tag{5}$$

Page 133. K (moment of inertia) $= Mr^2$, kinetic energy of a rotating body $= Kw^2/2$, in which everything is expressed in C.G.S. units; page 94, the product mv is called the momentum of the particle; page 115, kinetic energy W of a particle is given by $W=\frac{1}{2}mv^2$ (C.G.S. units) and by $W=mv^2/64$, where W is in foot-pounds, m in pounds, and v in feet per second (page 116).

Fuller and Johnson—Applied Mechanics.

Page 3. The term mass is commonly used to denote the quantity of matter that a body contains (page 33).

Page 5. Since $M=F/a$, the mass of a body may be measured by the ratio between any force acting upon it and the acceleration which the force produces.

If W is the force by which a mass M is drawn toward the earth and g the acceleration produced by that force,

$$M=W/g.$$

The unit mass will, therefore, weigh g units of force, whatever system of units may be adopted.

Absolute System.—In the absolute system, the unit of mass is assumed and the unit of weight determined from the equation $M=W/g$.

Page 6. *Gravitation System.*—In the gravitation system the unit of weight is assumed and the unit of mass derived from the equation $M=W/g$. Where the British units are used, the weight of the standard pound is chosen as the unit of force. The unit mass will therefore weigh g pounds. Since the force exerted by the earth on the pound weight varies with the locality, it is evident that the unit of force in this system is variable, unless the weight of the pound at some particular locality is taken as the unit, which has not been the case.

Since the weight of a body is the force exerted upon it by the earth, the units of weight are the same as units of force.

Page 194. Momentum of a particle of mass m and velocity v is equal to mv; page 195, angular momentum $=mvr=mwr^2$; page 197, centripetal force $=mv^2/r=mw^2r$; page 235. kinetic energy of a particle $=mv^2/2$; page 163, $I=\int r^2dW$.

Hancock—Applied Mechanics for Engineers.

Page 3. *Mass.*—The mass of a body is the quantity of matter it contains. Mass differs from weight, in that the weight varies with the position on the surface of the earth and with the height above the surface, while that mass remains the same. The engineer's definition of mass, viz., that it is equal to the weight divided by the acceleration of gravity (see Art. 76), may be expressed $M = G/g$. Both G and g vary for different localities, but the quotient is constant; that is, the quantity of matter in a body is independent of its position with reference to the earth. The weight of a body may be determined by means of a spring balance. Such a balance is the only true measure of its weight since the equal-arm balance gives the same weight regardless of distance from the center of the earth. The equal-armed balance really measures mass.

Page 70. $I = \Sigma y^2 dF$, $I = \Sigma y^2 dM$, $I = \Sigma y^2 dV$ for the area, mass and volume respectively; kinetic energy $= Iw^2/2$; page 128, $P = (G/g)a = Ma$; page 146, normal force $= Mv^2/r$.

Hoskins—Theoretical Mechanics.

Page 23. *Unit Mass.*—The unit mass is taken as the quantity of material in a certain piece of platinum arbitrarily chosen and established as the standard by act of the British Parliament. Thus unit mass is called one pound.

Weight.—The weight of a body is the force with which the earth attracts it, in accordance with the law of gravitation. From this law (Art. 39) it follows that the weights of bodies in the same locality at the surface of the earth are proportional to their masses. But if the bodies are in different positions on the earth or at different elevations above the surface, their weights may not be proportional to their masses.

Page 183. It will hereafter be assumed, unless otherwise expressly stated, that a kinetic system of units is employed, so that the equation of motion takes the form

$$P = mp.$$

For the purposes of the engineer the most convenient unit of force is the weight of a definite mass at the earth's surface. Such a unit, though not exactly the same for all localities, is sufficiently definite for most practical purposes.

Let the pound-force (already defined as the weight of a pound mass) be taken as the unit force, let the foot and second be taken as units of length and time, and let the unit mass be so determined as to satisfy the equation $P = m(v/t) = mp$.

The unit mass must now be defined as a mass whose velocity will increase by one foot per second during each second if acted upon by a force of one pound.

The required unit mass is therefore g times as great as the pound mass.

Page 247. $P' = mv^2/R$; page 276, momentum of a particle is proportional to its mass and its velocity; page 309, kinetic energy of a particle $= mv^2/2$; page 332, $I = \int r^2 dM$.

Huntington—Essentials of Elementary Dynamics.

Page 7. The force of gravity, or weight, W. The unseen force which gives a body, when allowed to fall freely from rest, in vacuo, in a given locality, the observed acceleration g is called the force of gravity on that body in that locality.

By the local weight of a body in any specified locality we mean the force of gravity on that body in that locality.

By the standard weight of a body we mean the force of gravity on that body in the standard locality (that is, in any locality where g has the standard value of g_0).

To determine the weight of a body in any locality we have merely to suspend the body on a spring balance, in vacuo, in that locality, and note the reading of the scale; for, since the body is at rest, the upward force exerted by the spring must be precisely equal to the downward force of gravity.

Whenever we use the word weight without specifying any particular locality, we shall always mean the standard weight of the body.

The relation between the local weight W_1 and the standard weight W_0 of a body is given at once by the fundamental proportion between force and acceleration; thus $W_1/W_0 = g_1/g_0$, or $W_1/g_1 = W_0/g_0$ where g_1 is the local value of g, and g_0 the standard value. Hence, although W_1, as well as g_1, varies in different localities, the ratio W/g for any given body is the same in all localities.

If the standard weight of a particle is W_0, we know that the acceleration produced in that particle by a force W_0 is equal to g_0. Hence, if a is the acceleration produced in the same body by any other force F, then, by the fundamental proportion, $F/W_0 = a/g_0$, or $F = (W_0/g_0)a$; and this is usually the most convenient form in which to write the differential equation of motion.

Page 9. Inertia, amount of matter, or mass. (*a*) One body is said to have more inertia than another body if it requires a larger force to give it a specified acceleration.

In particular a body is said to have the same inertia as the standard pound body (or the standard kilogram body) if it requires a force of 1 lb. (or a force of 1 kg.) to give it the standard acceleration g_0.

(*b*) A body is said to contain one pound of matter (or one kilogram of matter) if it has the same inertia as the standard pound body (or the standard kilogram body).

It should be noticed that if all bodies were composed of the same material, the amount of matter in a body could be estimated at once by the size of the body. But since this is not the case, we have no way of determining even what we mean by the amount of matter in a body except by measuring the inertia of the body, that is, by finding out how much force is required to produce in the body a given acceleration. For example, take the familiar case of a brick in a paper bag on the sidewalk.

(*c*) Again, a body which contains one pound of matter (or one kilogram of matter) is called a pound mass (or a kilogram mass).

That is, to say that a body has a mass of one pound (or a mass of one kilogram) means simply that the body requires a force of 1 lb. (or a force of 1 kg.) to give it the standard acceleration g_0.

From these definitions it is obvious that the standard weight of a pound mass is 1 lb. force and the standard weight of a kilogram mass is 1 kg. force.

Page 11. (*b*) The momentum of a particle of weight W at any instant is $(W/g)V$.

Page 12. (*b*) The kinetic energy of a particle W at any instant is K.E. $=(W/g)V^2/2$.

Lanza—Applied Mechanics.

Page 11. The product obtained by multiplying the number of units of mass in a body by its velocity is called the momentum of the body.

Page 13. Now, if W represents the weight of the body in pounds, and m the number of units of mass in its mass, we must have, in order that the statical and dynamical measures may be equal, $W=mg$; hence $m=W/g$, *i. e.*, the number of units of mass in a body is obtained by dividing the weight in pounds, by the value of g at the place where the weight is determined. The values of W and of g vary for different positions, but the value of m remains always the same for the same body.

Unit of Mass.—If $m=1$, then $W=g$; or, in other words, the weight in pounds of the unit of mass (when the gravity measure is used) is equal to the value of g in feet per second for the same place.

Page 77. $F=ma$; page 79, kinetic energy $=mv^2/2$, or $Wv^2/2g$; page 81, centrifugal force $=mv^2/r=Wv^2/gr$; but, page 105, $I=\Sigma r^2w$.

Martin—Textbook of Mechanics.

Page 6, Vol. I. This force is known as "Weight" and is the result of the attraction which the earth exercises on all bodies in accordance with the law of gravitation.

Page 72, Vol. II. In engineering practice the unit of force is always taken as the force with which the earth attracts a certain lump of platinum (marked "P. S. 1844, 1 lb.," and carefully preserved in London). This force is called a pound and this force is our unit of force.

The unit of acceleration has always been fixed as an acceleration of 1 ft. per second per second.

The units of force and acceleration having been thus fixed it remains to determine the unit of mass.

Page 71. Momentum is defined as the product of the mass of the moving body and its velocity.

Page 73. This means that the unit of mass must be a quantity of matter which weighs $g(=32.19)$ pounds. This unit of mass is called the gravitational unit of mass, sometimes also the engineer's unit of mass.

Page 73. $F=ma$; page 112, $R=mv^2/r$; page 131, $I=\Sigma r^2 m$; page 176, kinetic energy of translation $=Mv^2/2$; etc.

Maurer—Technical Mechanics.

Page 138. In Art. 2 we explained also that the word weight is used in at least two senses in common parlance. But we will continue to use it in a single sense, to connote the earth pull on a body, and we employ a separate word (mass) to connote the amount of substance or stuff in a body.

Page 139. When any forces are applied successively to the same body so as to make it move in a straight line, then the acceleration is proportional to the forces respectively. That is, $F/F'=a/a'$. Hence also $F/W=a/g$ or $F=(W/g)a$.

Page 142. Whenever a force acts on a body so as to make it move in a straight line, then the acceleration produced is proportional to the force directly and to the mass of the body inversely. This proportionality can be put into the form of an equation, $F=Kma$.

Page 143. If we take the pound as the unit of force, the foot per second per second as acceleration, then the corresponding unit of mass (to make $K=1$) is such a mass as will sustain an acceleration of one foot per second per second under the action of a force of one pound. This unit of mass has no generally accepted name, but it is sometimes called "engineer's unit of mass," also "slug" and "geepound."

$$1 \text{ slug} = 32.2 \text{ pounds (mass)}.$$

Page 168. $I = \int dMr^2$; page 194, kinetic energy (translation) $= Mv^2/2 = Wv^2/2g$; momentum of a particle $= mv$.

Merriman—Mechanics of Materials.

Page 438. The term moment of inertia originated from the theory of a rotating body. When a body is put into a rotary motion around an axis, each particle offers a resisting force by virtue of its inertia, this force being proportional to the *mass* m of the particle and to its acceleration. Let a be the acceleration of a particle at the distance unity from the axis, then the acceleration of a particle at the distance z is za. The resisting force of inertia of that particle is mza, etc.

Merriman—Elements of Mechanics.

Page 147. In all the above formulas involving inertia and kinetic energy, the letters W and g enter. W has been defined to be the force with which gravity acts upon the body as determined by a spring balance, and g has been defined as the acceleration of the body in a vertical fall. Both W and g are hence measures of the same force in different ways, and accordingly their ratio W/g must be constant at all places. This ratio depends only upon the quantity of matter in the body, and it is generally called "mass" in higher works on theoretical mechanics and is designated by M. Accordingly the force of inertia, may be written $F = Mf$, and the kinetic energy of a moving body may be expressed by $K = \frac{1}{2}Mv^2$. These works also use a unit for W different from that employed in this book, or they determine M by balancing it on a lever against a body of known mass. The system of units used in this book is called the "gravitation system," and is the one generally employed by civil, mechanical and mining engineers. The other system of units is of special value in celestial mechanics where bodies have no weight in the sense here employed.

Slocum—Theory and Practice of Mechanics.

Page 71. In other words, the lead block offers a greater resistance to change of motion than the wooden one; or, what amounts to the same thing, the ratio F/a or m, is greater for the lead block than for the wooden one. Thus the ratio m, which is constant for any given body, is different for different bodies. This is expressed by saying that with each body there is associated a definite constant m (or ratio of force to acceleration), which expresses the amount of its resistance to change of motion, or its inertia, as it is called. This constant m, which measures the inertia of a body, is called its mass.

Page 72. Therefore if the weight of unit mass is chosen as the unit of force, and is assumed as the unit of mass, the fundamental relation becomes

$$W = mg \times 1$$

The technical or gravitation unit of mass is therefore g times as great as the absolute unit of mass.

Page 95. Momentum $= mv$; page 79, kinetic energy $= mv^2/2$; page 105, kinetic energy of rotation $= Iw^2/2$.

Smith and Longley—Theoretical Mechanics.

(Mass seems not to be defined.) Page 91. Weight is the force of gravity; page 92, in scientific units, force $=$ mass $\times$ acceleration, in technical units, force $=$ mass $\times$ acceleration g; page 90, momentum $= mv$; page 113, kinetic energy $= mv^2/2$; page 29, moment of inertia $= \int r^2 dm$.

Wood—The Elements of Analytical Mechanics.

Page 16. Mass is a quantity of matter. If we conceive that a quantity of matter, say a cubic foot of water, earth, stone, or any other substance, is transported from place to place, without expansion or contraction, the quantity will remain the same, while its weight may constantly vary. If placed at the center of the earth it will weigh nothing; if placed on the moon it will weigh less than on the earth, and if placed at any place in the universe its weight will be directly as the attractive force of gravity and since the acceleration is also directly as the force of gravity we have

$$W/g = \text{constant},$$

for the same mass at all places. This ratio for any contemporaneous values of W and g may be taken as the measure of the mass, as will be shown in the two following articles. The weight in these cases must be determined by a spring balance or its equivalent.

Page 18. *Unit of Mass.*—If it is assumed that $c = 1$, as in the preceding article, the unit of mass is virtually fixed. In (20) if $W = 1$ and $g = 1$, then $M = 1$; that is, a unit of mass is the quantity of matter which will weigh one pound at that place in the universe where the acceleration due to gravity is one. If the quantity of matter weighs 32 pounds at a place where $g = 32$ feet, we have

$$M = 32 \div 32 = 1,$$

hence on the surface of the earth a body which weighs 32 pounds (nearly) is a unit of mass.

Page 44. $Mv^2/2 =$ vis viva; page 50, $Mv =$ momentum; page 202, the energy of a rotating body $= Iw^2/2$.

Woodward—Rational and Applied Mechanics.

Page 175. The measure of mass. N. B. Throughout this chapter the letter F will always represent an unbalanced force, or the unbalanced resultant of two or more forces. Returning now to our equation which declares the equality of two ratios, and substituting W for F_1, and g for a_1, we have, omitting subscripts,

$$F/W = a/g.$$

This is a most important fundamental equation, and one to which or to its immediate derivatives, the student will at once return when he has a real problem in dynamics to solve.

The first derived form is

$$F = (W/g)a, \tag{2}$$

in which the ratio W/g explicitly appears. It is quite universally represented by one letter, m, which stands numerically for the mass of the body which weighs W. Hence the simple formulas $m = W/g$ and

$$F = ma, \tag{3}$$

a formula is used in all systems of units, and should be memorized as: The (unbalanced) force (F) is (numerically) equal to the number of units of mass in the body acted upon, multiplied by the number of units in the acceleration produced, or elliptically: *The unbalanced force equals mass times acceleration.*

Page 316. Momentum is mv, kinetic energy of a moving mass is $Mv^2/2$; page 215, to get I (for masses we shall multiply an element of mass by the square of its distance from an axis in space; and $W/g = m$, that is, a unit of mass weighs 32.16 pounds under standard conditions.

Wright—Elements of Mechanics.

Page 57. The weight (or mass) of a body is therefore constant, but the force of gravity on the body varies from place to place.

Page 59. The unit force is naturally taken to be the force with which the earth attracts the unit weight, the standard pound. The unit force is named a pound.

Page 61, footnote. The term mass, however, belongs strictly to an absolute system of units only, and the innovation adds confusion to a system already confused enough. See, for a discussion of this question, *Nature*, vols. 37–46—particularly a paper by Professor Greenhill, Vol. 46, pp. 247–252.

Page 49. The product mv is called momentum; page 50, the expression $mv^2/2$ is the energy of the moving body; page 53, summary of the laws of motion, $F=ma$, $Ft=mv$, and $Fs=mv^2/2$; page 60, in gravitation units $F=Wa/g$, $Ft=Wv/g$, $Fs=Wv^2/2g$; page 291, $I=\Sigma wr^2$.

Perry—Calculus for Engineers.

Page 26. In Practical Dynamics one second is the unit of time, one foot is the unit of space, one pound (what is called the weight of one pound in London), is the unit of force. To satisfy the college men who teach engineers, I would say that "The unit of mass is that mass on which the force of 1 lb. produces an acceleration of 1 ft. per sec. per sec."

We have no name for unit of mass, the engineer never has to speak of the inertia of a body by itself. His instructions are "In all dynamical calculations, divide the weight of a body in pounds by 32.2 and you have its mass in engineer's units—in those units which will give all your answers in the units in which an Engineer talks."

Perry—Applied Mechanics.

Page 40. When a body is in motion, it possesses kinetic energy equal to half its mass (its weight in London in pounds divided by 32.2 is its inertia, which is usually, but we think unwisely, called its mass), multiplied by the square of its velocity in feet per second.

Page 593. $M=$ mass or inertia $=w/g$, $mv=$ momentum, $\frac{1}{2}mv^2=$ kinetic energy; page 254, kinetic energy of rotation $=\frac{1}{2}Ia^2$ where I is moment of inertia, that is, the sum of all such terms of mass of a little portion multiplied by the square of its distance from the axis of rotation.

Perry—The Teaching of Elementary Mechanics.

Page 58. The unit of inertia (inertia is now stupidly called mass and denoted by the letter m) is called a slug, being 32.2 times that of the standard piece of stuff, because it has been found by experiment that the unit force produces upon it an acceleration of one foot per second per second. Hence in engineers' calculations the numerical value of m in slugs $=$ weight in pounds in London $\div$ 32.2.* These units with the foot and second may be employed in any dynamical formula, and there is no curious factor needed. Professor Greenhill is greatly with me, but he objects to the use of m or the idea of mass (inertia) in all dynamical formulæ. I cannot agree with him in this, and, I think he is alone. It is most important to introduce kinetic ideas in the form:

Acceleration $a \propto$ force F. Now weight W is a force producing the acceleration g; therefore

$$F/W = a/g.$$

But surely when a boy has thought about this we may go further and say

$$F = (W/g)a$$

and call W/g the inertia (or mass) of the body, denoting it by the letter m, so that always $F = ma$.

Rankine—Applied Mechanics.

Page 482. The Mass, or Inertia, of a body, is a quantity proportional to the unbalanced force which is required in order to produce a given definite change in the motion of the body in a given interval of time.

It is known that the weight of a body, that is, the attraction between it and the earth, at a fixed locality on the earth's surface, acting unbalanced on the body for a fixed interval of time (*e. g.*, for a second), produces a change in the body's motion, which is the same for all bodies whatsoever. Hence it follows that the masses of all bodies are proportional to their weights at a given locality on the earth's surface.

Page 486. When the unit of weight is employed as the unit of force, instead of the absolute unit, the corresponding unit of mass becomes g times the unit just mentioned; that is to say, in British measure, the mass of 32.2 bs., or in French measure, the mass of 9.81 kilograms.

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* The more correct value is 32.182, g at London.

Page 485. $Q = mv^2/r$, but page 491, $Q = Wv^2/gr$; page 499 actual energy $= mv^2/2 = Wv^2/2g$. Actual energy is expressed in foot-pounds. Page 514, the moment of inertia is either sum of such terms as mr^2 or Wr^2; the second is the more convenient in Applied Mechanics.

Ziwet and Field—Introduction to Analytical Mechanics.

Page 120. Physical bodies are distinguished from geometrical configurations by the property of possessing mass; and the way in which this property affects their motions is studied in that part of mechanics which is called dynamics.

We may think of the mass, or quantity of matter, in a physical body as a certain indestructible content in the portion of space occupied by the body. By the methods of weighing explained in physics we can compare these contents of different bodies; and, taking the mass content of some particular body as the standard unit we can express the mass of every body by a single real number. We here confine ourselves to so-called gravitational masses; the number that expresses such a mass is always positive, and it remains constant in whatever way the body may move.

The student must be warned not to confound mass with weight. The weight of a body, as we shall see later, is the force with which the body is attracted by the earth; it varies, therefore, with the distance of the body from the earth's center, and would vanish completely if the earth were suddenly annihilated; while the indestructibility of mass is the first fundamental principle of chemistry and physics.

The modern developments in the theory of electricity may, and probably will, lead to a better understanding of the intimate nature of mass or matter. But this would hardly affect ordinary mechanics which will always retain a wide range of applicability.

Page 121. The unit of mass in the C.G.S. system (Art. 6) is the gram, in the F.P.S. system the pound.

Page 132. The product mv of the mass m of a particle into its velocity v is called the momentum, or the quantity of motion, of the particle.

Page 137. The quantity $\frac{1}{2}mv^2$, *i. e.,* half the product of the mass of a particle into the square of its velocity, is called the kinetic energy of the particle.

Summary of Usages of Some Terms and Formulas by American Authors.

1. Weight as earth-pull exclusively. All American authors listed except Wright who takes weight to mean also quantity of matter (in common units).

2. Mass as quantity of matter exclusively. All (American) authors listed except possibly Church, Merriman, Slocum, Smith and Longley, and Woodward; some of these apparently give the term mass several definitions which do not seem to be equivalent.

3. $F = ma = (W/g)a$, where W is earth-pull. Dadourian, Fuller & Johnson, Hoskins, Lanza, Martin, Slocum and Wood.

4. $F = (W/g)a = ma$. W is earth-pull. Church, Hancock, Maurer, Woodward.

5. $F = (M/32.2)a$, ‘‘common units''; $F = ma$, C.G.S. units. Dubois, Franklin and MacNutt, Smith and Longley.

6. $F = (W/g)a$, where W is earth-pull, for common units; $F = ma$, for C.G.S. units. Huntington and Merriman.

7. $F = (W/g)a$, where W is amount of matter, ‘‘for common units''; $F = ma$ for C.G.S. units. Wright.

8. Momentum $= mv$. All except Hancock and Merriman who seem to avoid the term momentum entirely, and Huntinton who writes momentum $= (W/g)v$.

9. Kinetic energy $= \frac{1}{2}mv^2$. All except Huntington and Merriman, who write kinetic energy $= \frac{1}{2}(W/g)v^2$ except for C.G.S. units possibly; and Franklin and MacNutt who write

$\frac{1}{2}mv^2$ or $\frac{1}{2}mv^2/32$, depending on units (see end of abstract from their book).

10. Moment of Inertia $= dm.r^2$ or mr^2. All except Lanza who takes $I = wr^2$; Fuller and Johnson who write $I = \int r^2 dW$; Wright, $I = wr^2$; Wood, both wr^2 and mr^2.

REPORT OF THE COMMITTEE ON THE TEACHING OF PHYSICS TO STUDENTS OF ENGINEERING.

The Committee on Teaching Physics to Engineering Students wishes to make a report of progress and to offer suggestions for a discussion which may help the Committee to come to a final conclusion. The reports of other committees, which are making progress, will no doubt assist the Committee on Physics. When the Committee on Teaching Mechanics has concluded its work, it will have considered the matters which trouble physicists; and when the committee, of which Dr. Mann is the representative, has found out, as he intimates, that it is physics which causes much of the trouble for engineering students, probably Dr. Mann will also tell us in what way physics is deficient and then we may be able to improve the methods of teaching.

The Committee on Physics consists of nine members. Calls have been issued for three meetings. Each of these meetings has been attended by two members only. In each case, the chairman and Professor Franklin.

Complete copies of the discussion at the Princeton meeting were sent to all members of the Committee with requests for further suggestions. Answers were received from three members only of the Committee. These answers were abstracted and a second report was sent to all members, which brought forth little additional information. The chairman has discussed the subject with many teachers of physics, several of whom are present.

At the Princeton meeting, the discussion took the form of a general criticism of the methods of teaching physics. Much is said of the confusion in the students' minds regarding "mass" and "weight." The conclusions of the Committee on Mechanics regarding mass and weight are certainly acceptable to the Committee on Physics. The physicist does not understand how there can be any such confusion. I have never heard the question discussed except in this Society. Professor Stewart says the confusion arises after the student has passed beyond general physics. For what happens to the students' ideas at this time, the teacher of physics is hardly responsible. What does the physics teacher do that is wrong? We wish to know this in order to proceed.

So far in its deliberations, the Committee has received but one specific criticism of the methods of teaching. This criticism refers to the lack of instruction in the principles of photometry and in the phenomena of radiation and the omission of these subjects from textbooks. I do not know of a single textbook of physics now in use, which does speak of both of these subjects. Therefore, the criticism is of small effect. There remains, however, the question how much of these subjects ought to be taught in general physics.

The preparation of a syllabus of physics was mentioned at the Princeton meeting. A majority of the Committee has expressed the opinion that this is not desirable. If a syllabus is required, a vote of the Society to this effect is requested.

The Committee proposes the preparation of two *questionnaires,* one to be sent to teachers and the other to practicing engineers.

The *questionnaire* for teachers should ask for information regarding: requirements in physics for admission to college; the minimum time to be given to instruction by lectures, recitations and laboratory practice; the distribution of time between the different sections of physics; the nature of the laboratory instruction and experiments; the content and the extent of class work. The purpose of the last question is to determine whether instruction in general physics should include a study of such subjects as dimensional equations, black-body radiation, wireless telegraphy, radio-activity, X-rays, etc. The *questionnaire* should also contain some general questions: whether calculus should be required in general courses and whether a different content of the course in physics should be given to different groups of engineers, architects, etc.

The *questionnaire* for engineers might include these questions: What are the criticisms of the teaching of physics; is there too much or too little laboratory practice; is the presentation of physics too mathematical; should calculus be used in general physics courses; what is the value of physics to the engineer.

Some members of the Committee are of the opinion that the time alloted to physics is much too short to cover the fundamentals of all the different divisions. It is required not only that the student shall be proficient in general physics, but the electrical engineer wishes him to understand the $1/2Li^2$ Law; the hydraulic engineer wishes him to be able to recite Bernoulli's Theorem; the illuminating engineer wishes him to know all about the radiation of a black-body; and the heat engineer wants him to be familiar with Carnot's Cycle. If such subjects are to be included in general physics, more time must be given to this study than is usual.

I would like to have an expression of the wish of the Society and to receive suggestions of further topics for investigation by the Committee. It is possible that the Committee can, following such suggestions, prepare a report which will be useful to the Society.

D. C. MILLER,
Chairman.

DISCUSSION OF THE REPORTS ON TEACHING MECHANICS AND PHYSICS.

Professor L. B. Spinney: In discussing this matter of the fundamental equation the important thing to keep in mind, as I see it, is that the mass of a body is a characteristic of that body quite as distinct as its volume. I believe a careful study of the question must lead one to this conclusion, although many students fail to grasp the fact. I agree with everything Professor Franklin has said; but I think we should remember that mass has to do with weight only indirectly. It is not by any means to be considered as a something derived from weight. Every one knows that the mass of a body may remain unaltered while its weight changes and even when its weight vanishes. Of course, we cannot actually so condition a body as to prove the latter part of this statement. In imagination, however, we may make the experiment and satisfy ourselves of its truth.

The equation $F = Ma$ is the fundamental equation. Mass is to be recognized as a definite property of matter; it is not W/G (weight over "gravity") nor is it weight transformed by any sort of operator. I cannot arrive at a notion of mass by this route and can only think of it as a definite and fundamental property of matter. It therefore seems illogical to me to approach the fundamental relation between force and mass by way of a consideration of weight.

Professor E. F. Coddington: I think we all have the same experience. When I hear a group of professors talk about force, mass, and acceleration I am not surprised that students become confused when we try to teach them the relation connecting these quantities. We are trying to prepare engineers to go out into practical work and solve practical problems. They approach these problems from the concepts they have gained from their experience in practical life. It seems to me that we must approach this subject in the same way, if we are to be at all successful in our teaching. We cannot begin with formal equations which have no meaning for the student. It seems to me that we must appeal to the concepts already possessed by the students. Professor Mauer has defined some of these concepts very nicely in his *Syllabus of Dynamics.* If we can start with clear conceptions of mass, force and acceleration, we should have no difficulty in teaching the law connecting these quantities. I find that the idea of acceleration is the most difficult for students to acquire. In deriving the equation which expresses this law I separate acceleration into the difference of velocities divided by the difference of the corresponding times, assuming that the rate of increase of velocity is constant during this time interval. I am of the opinion that the significance of this law can best be taught by means of a demonstration I would suggest a mass of considerable magnitude mounted on a car running on a horizontal track with the friction due to motion on this track reduced to a minimum. I would then vary the force and the mass and measure the increase of velocity in the given time in each instance. I would then show that the magnitude of these quantities, measured in whatever units we may choose to use, will satisfy the following equation

$$V_2 - V_1 = k\frac{F}{M}(t_2 - t_1)$$

where t_1 and t_2 are the clock readings at the beginning and end of the time interval used; V_1 and V_2 the velocities corresponding to these times; M the mass, F the horizontal force attached to the mass and k a constant depending on the combination of units used to express the magnitudes of the other quantities occurring in the equation. I would then show that, if the force be expressed in pounds, the mass in pounds, the time in seconds, and the velocity in feet per second, the numerical value of k will be approximately 32.2.

This method should enable the student to see the real significance of the constant in the above equation and that its value depends upon the units used and also that problems of falling bodies belong to a special case of a more general class which requires the use of this constant for their solution.

After having determined an approximate value for this constant, I would give them the value suggested by Professor Huntington in his definition of horse-power (see February Bulletin 1915) which is 32.1740 and would designate it by g.

I would then transform my equation as follows:

$$\frac{V_2 - V_1}{T_2 - T_1} = \frac{gF}{M}$$

or

$$\alpha = \frac{gF}{M}$$

or

$$F = \frac{M}{g}\alpha$$

Professor G. W. Stewart: I am not very familiar with the work of this committee in the past and should hesitate, therefore, to criticize its failure to report on the possibilities of correlation, a subject which to me seems much more important than either that of definitions or methods of presentation. Here in this syllabus the committee presents mechanics in a form so elementary that a good course in physics covers practically all of it. Assuming that the student, before he undertakes this course in mechanics taught by an instructor in the engineering college, has already completed the required work in physics, the question at once arises, "Why ought he to study again this same elementary material, presented in a different book?" And, as I understand, it is proposed that the student take the mechanics presented in this syllabus, not in the sense of a review, but as a new course. All of us recognize that the general effect of such a procedure with a new book and a new instructor would be the exhibition of an amazingly strange amount of ignorance on the part of the student, resulting in a great loss of his time. The proper text for review is clearly the text already studied. The text used by the department of physics should be such as meets the approval of the engineering instructor in mechanics. If, then, it appears advisable to review the elementary physics, as indeed the syllabus before us indicates, let the instructor in mechanics at the beginning of his course assign this review in the text of physics used in the previous year. This method would save much time for the student. Time in the class in mechanics should be too valuable to use in reviewing elementary mechanics as a serious new study. For these reasons, I am compelled to consider correlation as more important than definitions and the details of presentation. Whether or not the suggestion I have made for the review is entirely practical, I must insist that our first interest is correlation between the subject in physics and the subject in the mechanics course.

Principal A. L. Williston: The chairman of this committee asks very forcibly, what is wrong with the teaching of physics? He says he does not know. He also stated that he heard no direct criticisms on the teaching of physics. This statement seems very strange to me because the literature of general education throughout the secondary schools is filled with criticisms of the teaching of physics in the secondary schools, and there is certainly sufficient published discussion and criticisms of physics in the elementary schools, at least, to put the committee on the track of some of the things that might be followed out in the college and the university. But a little later the chairman, it seemed to me, with equal frankness answered his own question, because he said "What happens to the student later, I do not know." What seems to me to be the trouble with physics is summed up in that sentence. The physics teachers do not know what happens to the students who go out into practical engineering work, who try to connect their work with study, and try to make their work directly applicable to the kind of work men are going to do. I am confining my discussion to the teaching of physics to the engineering student, and that one sentence, in my mind, summed up the difficulty completely.

Now, if I may say a word regarding what the other committee has placed on the blackboard. You have in the top line a series of equations which are supposed to deal with familiar units and which work altogether in the direction of the things the engineer has to deal with most. That is a fundamental idea, the conception of mass. The conception given is fundamentally wrong and inadequate, so far as the practicing engineer is concerned. He must have this conception and he wants the physicist to teach it to him in the elementary school, and he wants the boy to grow up with that conception in his skull.

Coming down to lines B and C, you have two equations, $F = Ma$ and $F = K$ times Ma. The two equations are identical. The two are fundamental. They deal with mass, and with things that happen to mass when force acts on mass and they are experimental laws that do not have to be derived. Why go back of that fundamental for that? When force acts on mass, it moves; and we express that either as $F=Ma$, or $F=KMa$. It does not matter which we use if we all use the same one. Now, the important thing is, and it is very important, that we should know when they are talking about M, whether it comes from equation B or equation C—whether this 32 belongs in there or not; whether K is one or something else.

The meeting at Minneapolis, when this committee was appointed, was to me one of the most interesting the Society has yet held. All of us were very much wrought up over the confusion that was created, distressing students' minds, the real misfortune that came to pass because a dozen different people gave a dozen different definitions and never took the trouble to tell the students in advance why they used this or that definition. Each speaker at this meeting said that if somehow all of us could get together, our teaching would be brought up in quality. Everybody who spoke was very willing indeed to make all kinds of concessions which might be necessary in order to bring about this happy condition. As a result of this love-feast the committee on mechanics was appointed. Then after it was appointed, I think it was Dr. Maurer who got to his feet and made a suggestion, and somebody else made a second suggestion, and finally the suggestions came faster and faster, and somebody said he would resign before he would do anything like that. But the first fact brought out at the meeting was all that the student wants, and that is, the importance of getting together. It makes no difference which equation we use. Let us find out which is the best, not from physics teachers, mechanics teachers, undergraduate students, or anybody else except from those out in the world where these fellows are going. Let us find out which is being used most, and if we are going to send the boys out into the world where one thing is going to be used more than another, let us frankly prepare our boys for the world they are going into and teach them in the language they will find used the most.

My suggestion to the committee on mechanics is that that is their most important job—finding out which of these two things is the most commonly used among practicing engineers; and second, induce just as many persons as possible to prepare boys for that which they find is most universally in use.

Professor F. C. Caldwell: At The Ohio State University we have been studying this question of correlation during the past year, together with the various methods of teaching. Among others we are considering the question of physics. There is a strong feeling, not only among our engineers, but in our physics department as well, that the old system where one person gives the lecture, another the recitation, and another the laboratory work is wrong. This coming year we are to try teaching physics as mathematics is usually taught. The classes are to be divided into sections so that one man will take a section and do all the work with it—recitation, demonstration and laboratory instruction. Thus the students in each class will be in the charge of one man for the whole work.

Professor E. W. Kellogg: Teachers, so far as I have observed, are drawn very largely from men who as students were of the first rank, and who in their studies revelled in pure science. On the other hand, there are a good many teachers, who as students were not quite so good, and it has been my impression that the second class of teachers is a little more successful. I think the explanation is very simple, that the lover of pure science is satisfied in his own mind with the purely scientific side of his subject. The other man is a little closer to the student's point of view, and he appreciates what the student wants in order to make the study interesting to him. He realizes that the student will not be interested unless he sees the practical bearings of the thing, and is a little more on the alert, a little more predisposed because of his own turn of mind, to always show the student the practical bearings of what he is teaching him. He will also omit teaching the student things for which he can show no practical application. I think there is not much hope that the teacher will be drawn more from that second class of men, because it is too much the law of nature that men of pure science will go into teaching. But a teacher finding himself disposed to enjoy the pure science can, by keeping in mind his predisposition and the necessity of going against his natural instincts to the extent of pointing out always the practical bearings and omitting what he cannot show the practical bearings of, perhaps offset the handicap he has.

Professor O. J. Ferguson: I should like to make just one comment upon this double topic. One difficulty I have with engineering students is to get away from the factor "*g*". In the application of this formula to some of our engineering processes, we have a very considerable trouble in getting them away from falling bodies. Constant acceleration is drilled into them to such an extent that a street car is supposed to accelerate at a constant rate, or anything else is supposed to change its velocity at a constant rate. That is one very practical difficulty that I meet with, and it seems to me that from my contact with the subject we specifically can make this criticism, that the derived formula is impressed upon the student as an important thing, whereas the fundamental formula is not left as the superlative thing.

Dr. C. R. Mann: I am not arguing; I am just learning. I hope I may know something about this subject after a while. It seems to me that we have been discussing two distinct questions this morning. Mr. Williston has pointed out the fact that the theory of mechanics is encumbered with a large amount of metaphysical speculation. Elementary students of engineering should not be confused by introducing that. Professor Stewart has made clear that the important thing for teachers is to discover how they can get the subject matter across to the students so that they can use it. Professors of science and of engineering must consider both the metaphysical and the pedagogical sides; students of science, especially at the beginning. should not be confused by having presented to them more than one at a time.

It is a significant fact that physics, mechanics and calculus appear together among the subjects that cause the greatest amount of trouble in the engineering curriculum. Perhaps there is some source of difficulty common to all three. Perhaps it is possible for the committees on physics. on mechanics and on mathematics to find out what this common element is. My experience suggests the notion that this common element may be the idea of velocity at a point. which is the idea of the differential. Students are confused by this from the first and their confusion continues throughout the entire course. If there is such a common element of confusion. the only way to clear it up is for the departments of physics, mathematics and mechanics to agree on the most effective method of presenting these subjects and to work on the student. all to the same point and with the same method, in order that by the time he gets to his third year he may be able to use his fundamental sciences efficiently and well. This means coöperation among the departments.

Professor Miller has asked us to give a specific criticism of physics teaching. This incident occurred recently on the train.—you may think it was specially arranged for my benefit. but it was not. Two young men were seated behind me. An automobile truck stood outside the station at which our train stood—an automobile with solid rubber tires. One young man said, "Why do they use solid rubber tires on trucks and not on passenger cars?" The other volunteered the suggestion that this was because the greater speed of the passenger car might cause a solid tire to expand and get loose. The other replied. "I do not see why it would do that." The first answered "Didn't you ever study physics? Didn't you study centrifugal force and learn that when a stone is swung around on a string it pulls outward on the string?" "Oh yes." said the other, "but I never dreamed that such a thing had a practical application in life anywhere."

Professor D. C. Miller: I am personally sorry that the discussion has not brought out more specific information on the teaching of physics.

Dr. Mann: Should not physics as a rule go from the general to the specific application?

Professor Miller: I think physics teachers agree that it should. I do not think there is a teacher today who is not doing his best to teach men the things they will need in after life. For what other purpose do we spend our lives? Though we may not accomplish the result, the failure is not due to ignorance of the end desired. We are doing our best and we will welcome every real improvement of method.

Professor E. R. Maurer: Just a few words. I wish to make it perfectly clear that this syllabus which I described somewhat, is not a syllabus coming with a recommendation from the committee. I presented it here as a working basis. It was presented, however, with the consent of the committee. There are some mistakes in the syllabus, and any careful reader will find them. I had no time to make corrections. I have secured a number of good suggestions for the work of the committee. I hope that if anybody has a suggestion for the benefit of the mechanics committee he will let me have it after the meeting today or by letter.

REPORT OF THE COMMITTEE ON COÖPERATION WITH SECONDARY SCHOOLS.

Gentlemen of the Society: Your Committee on Coöperation with Secondary Schools has during the past year devoted considerable attention to the aims and methods of technical high schools throughout the country. Beside this, consideration has been given to the work of the departments of mathematics, physics, and chemistry in secondary schools, and special reports on these subjects are appended.

Regarding secondary education generally, it appears that schools of this grade, standing as they do *between* the grammar schools, with their aim of a widely general public education, and institutions of collegiate grade, with aims which are selective and decidedly more specific in character, are afflicted with a confusion of ideas which is quite appalling to anyone searching for a principle of unity. The *forms* of selection and guidance,—examinations, honors, departments, courses of study—are everywhere present, but there is also present the well-defined idea that a boy or girl should, if possible, be kept in high school, regardless of his own or his parents' inclinations, until he shall have reached the age of eighteen or nineteen years, unless he is earlier prepared for collegiate work; and the whole situation is badly blurred by the generally accepted American notion that one person is as good as another, and that any attempt at classification of student ability is in the nature of an invidious discrimination.

It would be presumptuous in the extreme for your committee to report a final solution of this problem. It is therefore constrained to ask a further extension of time in which to continue investigation.

It is impossible to overemphasize the importance of the recognition on your part of the value of a secondary training in and of itself, apart from preparation for more advanced work. To this end it is urged that the individual colleges, through accredited representatives, might well become much better acquainted than they are with the actual working of secondary schools, and with the details of the previous training of students who are later to come under their own direct supervision. The problem of technical secondary education cannot be solved by any single committee. There must be a broadly conceived consensus of opinion. The committee desires to invite communications from the members of the Society regarding this problem in its broader aspects. Invitation of this sort was extended informally at the Princeton meeting, but thus far without result. Extensive data regarding present technical high school practice are at hand, but critical opinion is lacking. It should be always borne in mind that only a small percentage of the students of these schools reach higher institutions.

The technical high school in this country had its origin in the growing conviction that the earlier classical education was itself special in character, and not suited to certain types of mind. This idea gained force from the educational doctrine of Mr. Spencer that knowledge directly applicable to material ends is of the greatest worth. At about the same time the notion gained wide acceptance that education should be based upon the development of innate faculties or propensities, rather than upon conformity to an ideal type, and that compulsion in school should give place to the arousing of interest.

These ideas are probably sound enough, but thus far they have too often been applied in a purely negative fashion. Classical education has been forced into the background, but its place has in many cases been taken by a nondescript melange of literary lectures, scientific prattle and fantastic sociological theory. Responsibility for successful accomplishment has been removed from the pupil and placed upon the teacher. The rather startling corollaries have been drawn that almost anything in the nature of science can be taught to almost any boy or girl if only it is made interesting enough; and that the chief sources of interest appear in material forms. It was confidently expected by many that the technical high school would be able, without any form of compulsion, to turn into educated men and women youngsters who for a hundred reasons had failed in the classical high school; and this miracle was to be accomplished largely through the agency of shops, drafting rooms, and instruction in the fine arts.

The foredoomed failure of any such attempt has tended to bring the technical high school into disrepute. As a matter of fact classical education is, of the two, much easier of attainment than technical education, for the simple reason that it follows along narrower lines, and does not demand much diversity of abilities. If technical education is worth anything it is worth working for, as well in its lower as in its higher stages. The question of responsibility for failure should be in either type of school placed exactly where it belongs. This can be done not by hasty generalization, but only by means of careful inquiry, under duly qualified authority, into individual instances.

The technical high school has, however, a higher mission to fulfill than gleaning after the classical and literary educational harvest. Its function can best be formulated under the headings of "aim" and "method."

The *aim* of the technical high school is nothing less than the democratization of education, and the glorification of the commonplace in experience. The classical high school is by tradition an aristocratic institution. The departments of common knowledge are beneath its consideration. The technical high school finds its mathematics in a steel square as well as in a Greek manuscript; its chemistry in the kitchen as well as in a learned discourse, and its physics in the machine shop as well as in the research laboratory. Language, native or foreign, is viewed as a means of expression and not as an end of art. Art is spelled in terms of service. The ideal of the technical high school is the ideal of the engineer and not that of the trickster in argument.

The *method* of the technical high school can be summed up in one word, "application." From the point of view of the technical high school an idea is not worth while unless it is directly or indirectly applicable. For this reason the work in the school should be so adjusted that the student may to the largest possible extent appreciate the applicability, and hence the value, of the knowledge and training he may acquire. Very often a fictitious "thoroughness" must be sacrificed in favor of this principle, and the traditional criteria of culture must give way.

If the technical high school is to serve as a preparatory school for advanced institutions, as it should, it will be necessary to recognize at once that the "preparation" it affords is not different from that which any year of human progress provides for the next year. The school itself is a disavowal of that notion of preparation, probably theological in its origin, which assigns specified tasks to specified periods, as things to be got out of the way before real progress is attempted. Differences between the technical high school and the engineering college must be differences in degree but not in kind. It is our firm conviction that the early recognition of this principle will work for the benefit of both lower and higher institutions.

This means that the graduate of the technical high school should be at a distinct advantage, other things being equal, when he enters the engineering college. This advantage need not necessarily be expressed in terms of economy of time in college. It should at least be recognized by exemption from work which is in a large measure repetitive, with the substitution of broader work of an advanced grade, if desired. This can be done without injustice to those entering from classical high schools, if properly adjusted. The somewhat widespread practice of bolstering up the older type of so-called classical preparation by refusing to recognize distinctly technical subjects of secondary grade is absurd to the last degree and serves in a measure to discourage the efforts of public school authorities to give to children of high school age a training that will be worth something to them. Yardstick methods of determining college preparation should be discarded, the sooner the better. The examination system was better, in that it did not require a superior student to waste his time. It may be necessary to permit students with three or four years of Latin and Greek to enter an engineering college without preparation in applied science, mechanical drawing, and shop practice, for such students may be found to possess great ability, and to suffer only from procrustean educational surroundings. But the assertion that such students are the better prepared by virtue of this antique training is to impose upon credulity too great a strain for endurance. And to force a student who has taken a thorough high school course in physics and chemistry to repeat that work in college in classes of beginners is either a crime or a howling joke, according to the student's point of view.

If the technical high school is to send its best to the engineering college, as it should, it must not be closely hampered by specific requirements. In this connection the recently adopted ''alternative plan'' of Harvard and Princeton, which is soon to be adopted by Yale, is commended to your attention. Not to encroach upon the preserves of your committee on college preparation, it may be said briefly that any system such as this, which sets a premium upon achievement in those departments of study which lead directly to advanced work in college, and leaves other details in the hands of secondary school authorities, seems likely to produce the best results. The question of foreign language we must leave for the present, as the colored preacher said, ''in the hands of an all-wise and unscrupulous Providence.''

Respectfully submitted,
L. F. Rondinella,
H. T. Clifton,
C. M. Wirick,
H. E. Webb, *Chairman.*

Mathematics for a Technical High School.

Recent attacks upon the value of mathematics as a high-school study have served the useful purpose of stimulating a careful inquiry on the part of high-school teachers as to the content of the courses which are given; whether these criticisms have served any other useful purpose is open to doubt.

Investigation along the line mentioned is, however, proving not unfruitful. It is showing that the spirit of two or three decades ago, which tried to separate knowledge into wholly distinct compartments, left little of vital import in the mathematical compartment except queries regarding the relative speed of a dog and a rabbit, or the ages of various members of a family, the latter sometimes running up to four variables. Geometry, instead of unfolding the mysteries of the heavens, became an endurance test in memory; and arithmetic, the one subdivision of the subject which dealt with actualities, was elbowed nearly out of existence. In recent years there has been a decided reaction in favor of significant or applied mathematics in schools. A movement toward this end has, however, met with serious opposition, partly from science teachers who felt that their prerogatives were in danger of infringement, and partly from certain ideally minded people who felt that the sheer beauty of the mathematical structure should not be marred by contact with sawdust or machine oil. The situation was further complicated by some extremely practical persons who asserted (and "got away with it" in some places) that mathematics *per se* is really no knowledge at all, but only a puzzle; and that practical people should do well enough to get the mathematics they needed when and where they needed it.

The danger of this situation lay in the possibility that mathematics might be made "elective." This would be much as if a man sitting down to a meal were to decide to make his liver elective. But all things are possible with the educational theorist.

In point of fact, however, the typical high-school mathematics of the last quarter century has been about as valuable an adjunct to education as the vermiform appendix is to digestion—a vestige of former utility.

To restore mathematics to its rightful place in the high-school curriculum seems likely to be the contribution of the technical high school to the educational practice of the country. There is no general agreement as to precisely what should be done. But the tendency is the same in all quarters, and that is, to regard as the legitimate province of the mathematical department *all that part of human knowledge in which the mathematical element is dominant.*

This means that in a technical high school a course in algebra is likely to be a composite course based on algebra and including such topics as measurement and approximation, percentage of error, average, alligation (mixtures), levers, pulleys, inclined plane, belting, gearing and shafting, cutting speed, specific gravity, temperature, partitive proportion as applied in elementary chemistry, work and energy, uniform motion, horse-power, and problems based on a few of the best known and most frequently applied theorems of geometry. The notion of rectangular coördinates is also introduced and applied to simple cases. Logarithms are introduced early and employed freely, and the use of the slide rule is taught where this is practicable.

Such a program as this involves the extension of the course beyond the limits of a year, and also involves the elimination of some fancy steps in factoring, some extreme complexities of complex and other fractions, and quite a large number of made-to-order problems. But courses of this sort have proved their worth as vital to the beginnings of anything approaching a technical education.

Geometry must be considered as a whole. It is true that in its essence the science of geometry as we have it today is philosophical rather than technical. But if the concept of a well-ordered logical structure embodying the principles of three-dimensional space is to be presented to the youthful mind, it may as well be much as Euclid left it. If this notion is abandoned, a comparatively short time is needed for the presentation of the most important geometric laws, with the assurance that they accord with common sense and with the actual facts. But the wisdom of a complete abandonment of formal geometry is dubious, to say the least, despite the earnest conviction of Mr. Spencer.

Time may be saved, however, in the beginnings of the subject, if it is recognized that a categorical set of independent postulates is beyond the powers of a high-school student, and a somewhat more inclusive list of fundamental assumptions is taken, more or less arbitrarily, as a starting point. The theory of limits, as ordinarily taught in a high-school course in geometry, is inadequate, and generally imperfect. It had better be omitted and only commensurable cases considered. In a technical high school great emphasis should be placed on those theorems which lead directly to practical applications, and time should be allowed for the consideration of such applications. Simpson's rules and the prismoidal formula are easily established by elementary methods, and a great many practical problems combining geometric and algebraic methods can easily be assembled.

The tendency in a secondary-school course in trigonometry is to lay great emphasis on the solution of triangles. The demand in higher institutions is for ability in the transformation of trigonometric expressions. The possibilities in this direction are extraordinarily wide, and it is quite possible for a student, who has had under one instructor considerable drill in transformations, to fail in the case of a problem of this sort which has been set by another instructor. A definite agreement as to the character of abstract trigonometric work, and the value of the various methods of solving triangles would be of great value to the technical high school teacher.

With anything like the proper emphasis on applied problems, and in view of the generally accepted standard of intricacy on abstract work which a student is expected to meet, the high-school course in mathematics is overloaded. Students who are not going on with advanced work are entitled to an elementary course in strength of materials to supplement and correlate their work in mechanical drawing and elementary mathematics. Such a course may or may not be acceptable as a "unit" for college entrance. But if time is to be allowed for it in a secondary school, some matters must be set aside. There is as yet no definite agreement as to what can best be spared. But there is entire accord as to the necessity of eliminating the anomaly of a thorough familiarity with mathematical processes, combined with no knowledge whatever of their usefulness.

One suggestion regarding solid geometry is at hand: to the effect that the course might well be shortened by the elimination of those theorems pertaining to the geometry of figures on a spherical surface. This work is of little value when separated from the spherical trigonometry, as it generally is, in point of time, if not in point of fact. It might well be included in a college course in spherics, which would include also applications to civil engineering, navigation, and astronomy.

Higher algebra as a high-school course is taken by very few students, as a rule, and the ground which it covers is usually gone over again in college. It is no longer required for entrance, and its value as a high-school subject is dubious.

It is the desire of the committee that detailed consideration be given to the various items above mentioned, and that criticism of the same be sent to the committee at an early date.

H. E. Webb.

Physics in the Technical High School.

The problem of the engineering college is as closely linked on the one hand with the problem of the preparatory school as it is on the other with the engineering profession.

This committee has undertaken at this time to consider the relation of the technical high school to the engineering college. I have been asked to summarize the findings or suggestions, if such there be, in the teaching of elementary physics.

I would much prefer to discuss the teaching of elementary physics in high schools as a whole; for it has not seemed to me, at least in the somewhat limited field with which I am familiar, that the engineering colleges are as much concerned with the product of the technical high school as they are with the product of general high schools or other preparatory schools. If we may summarize all of our previous discussions, we are earnestly striving for a physics course which in the hands of a good teacher will meet the needs of the boy rather than the requirements of advanced research work.

There will appear later in the report some questions, replies to which, if followed out quantitatively, would give us some facts upon which to base further action.

It will also appear that under the conditions and with the limited resources with which this investigation has been attempted, little in the way of facts can be presented to the Society. If, however, there is any suggestion which may be considered worthy of future action by the Society, some gain may be counted.

Since our problem as a whole is to be interpreted as a problem of securing coöperation between the engineering college with its department of physics and the technical high school or other preparatory school with *its* department of physics, perhaps such suggestions as we may have will be of some assistance to your physics committee and help to promote the coöperation so greatly to be desired.

The High School Course.

The first step in our work was to make a general request to those of the members of the Society listed in the department of physics, to deans of engineering schools, to professors of engineering subjects and to such others known to the writer as would seem to be interested in the problem and its solution and capable of offering constructive suggestion to your committee. The response to this general request was gratifying and the result may be summed up by the following quotations.

"I know of no single subject billed to furnish better training or better information for the boy or the girl who is going out into the industrial and business world."—J. M. Jameson.

"The high schools have come to agree to a body of fundamental principles which any good course will include and the colleges base their examination both written and laboratory on these principles, etc."—N. Henry Black.

"Every teacher should be free to give practically his own course, and nothing is more fatal to good teaching than the hard and fast syllabus which practically determines the year's work."—H. G. Gale.

"A good deal of observation has convinced me that a failure to interest and benefit students in physics in secondary schools arises from three causes; first, the subject has been placed too early in the course; it should preferably come in the fourth year and never for any reason earlier than the third. Second, the incompetence of the teacher, either because he lacks the requisite knowledge of the subject or because of his inability to arouse interest in it. Third, the tendency so often apparent to spend too much time on a few popular applications of physics rather than on the exposition and illustration of physical principles.

"A combination of an inspiring teacher, one of the standard text-books, and a year's course of illustrated class-room instruction and simple laboratory work should satisfy the requirements for entrance to a first course in any college.

"The high-school course should furnish a thorough knowledge of first principles and a general survey of the subject to give the student a fair idea of the relations of different parts of the subject to one another."—Henry S. Carhart.

"Now all I ask of any secondary school teacher of physics, is that he teach the pupils to use what brains the pupils have. In other words, to teach the subject in such a way as to produce independent thinking. I recommend that they do not try to cover too much ground, but to hammer home a selected list of fundamental principles. Physics taught in such a way as to give a student the best preparation for his life work, will also give him plenty of preparation for entrance to college.''—O. C. Lester.

''In all these cases what the student really wants is to be able to think and think accurately and to a certain extent quantitatively about physical phenomena. That is, *he needs to have (a) the point of view of physics, (b) a very few fundamental principles as his ever ready tools of thought, and (c) as much practice as possible in applying these few tools to all sorts of practical questions.* That is, to my mind a high-school course should consist of a few fundamental principles and a great many practical problems grouped around them; and its chief aim should be to make the boy think straight.''—H. N. Davis.

''In my years of teaching, I have many times heard representatives of the physics department on various faculties say that the high-school work was not done very well; but I have come to feel that this high-school work is done much better than the college man knows and it is simply prejudice or ignorance on his part which allows him to talk in this way.''—L. P. Breckenridge.

''One considerable obstacle to progress in the past has been the failure on the part of the college instructors to appreciate the development of the sciences in the secondary schools. They need much information on this point, especially as the feeling is quite general that too advanced work is at times attempted in the training schools. When college men can be assured that the same degree of thoroughness is required in the sciences as in the classics, there will be no question as to the recognition of the work. I believe this is not true today and is largely due to the variety of work required in the secondary schools.''—G. C. Anthony.

''The technical high schools need as competent teachers as they can employ to teach the subject of physics and the college needs as thorough a preparation in this subject as the technical high school can give.''—H. M. Raymond.

''It seems to me that you have an excellent opportunity to point out the great need for a readjustment of emphasis that must be made if the high-school physics is to form a foundation for technical school engineering work.

"A few fundamental notions of statics, power, friction, heat and mechanics as applied to gas and steam engines and electricity of a commercial type should form almost the entire course, if its use to the engineering student is considered. Descriptive courses that go all over the field of physics form a very shifting foundation."—J. A. Randall.

"The physics of the technical high school will be strengthened by the courses in mechanical drawing and shop practice. These are indispensable adjuncts to the later courses in applied physics; and they can be made helpful from the beginning.

"It takes time and skillful teaching to develop a genuine understanding of the fundamentals of mechanics, and this more than anything else is the necessary foundation for the engineering courses at college.

"If the school offers other courses following this, a year and a half general physics should be planned on the basis of equal value to a college course and so should expect college credit to be given for it."—S. E. Coleman.

"*So long as the colleges insist on teaching high-school physics instead of college physics, so long will we have the problem that your committee is considering.* I see but one solution and that may be stated as follows: 1st, the high school to teach physics as presented in our best high-school texts, the work to be accompanied by proper laboratory work; 2d, the college to demand physics for admission, and require physics that measures up to sixteen ounces to the pound; 3d, the college to teach physics from the mathematical side and not from the elementary experimental side."—H. N. Chute.

1. "The topics chosen and the method pursued. should be determined by the intellectual needs and interests of pupils of secondary school age. *College admission tests in physics should be made to depend upon the secondary school subject, when properly organized, and conducted, and not vice versa.*

2. "The teacher should put out of his mind the thought that each pupil before him is aiming to become a specialist in physical science, or that the study of physics is his main interest in life. Instead of following the logical order of topics as this would present itself to an expert physicist, he should follow the psychological order as this reveals itself in the natural working of an intelligent and curious mind of secondary school age."—Nicholas Murray Butler.

Practically all of these writers seem agreed upon the field of the first course in secondary school physics; that is, to teach the few fundamental principles of scientific method and of physics itself, to teach them thoroughly, aiding this thoroughness by the use of the student's interest in practical applications and familiar household operations and appliances. Particularly is this true in the technical high school; the really good teacher will reach the proper balance and meet the needs of his pupils.

But above all, it is essential to induce the student to *think;* to reason from cause to effect, from fact to principle, and principle to result; and in all to depend upon himself, upon his own knowledge and power to reason and to gain knowledge and relate it to the facts at hand.

It is desirable to point out, as the basis for a definition of the relation of the physics of the technical high school to that of the engineering college, some suggestions based upon the idea of coöperation between teachers in these institutions.

Coöperation.

Let there be a keener interest on the part of the colleges of engineering in the technical high schools and other preparatory schools. This may be shown in some provision for opportunity for college professors and instructors to visit the preparatory schools, to become acquainted with their teachers, and to devise means of coöperation with those teachers in solving their common problems.

The mutual ignorance of college teachers and high-school teachers of their respective problems, and the unfamiliarity of both with the technical world and its problems, is largely responsible for the *existing* hiatus between high-school work and college work. Why can we not have some definite understanding as to what field the high school should attempt to cover, where the college should start its entering student, and where it should leave him in relation to the engineering profession?

Is it possible to standardize high-school and college work to the extent that their relative difficulty may be determined more or less closely? Shall we say, then, that the engineering college shall require elementary physics for admission, this to cover the field suggested above? Also, that the engineering college shall itself give or shall accept from its related college of arts and sciences, a college course in physics, built upon this elementary course, with its well grounded principles and practice, and affording that training in correct methods of mathematical reasoning and in precision of measurement which shall meet a reasonable requirement for applied work in the special branches of physics and engineering?

This is one line in which the high-school teacher requests coöperation.

Another, assuming that physics is taken in the third year of the high-school course, relates to a fourth-year course in applied physics, which will be based upon the first course, and yet receive recognition in the college as worthy of credit.

"I believe that a great advantage accrues to a student of engineering, especially of electrical engineering, who does more than a year's work in physics in the high school. Six years, beginning in the third high-school year, is none too long. I also believe that the teaching of the elements of a subject is distinctly better done in secondary than in higher schools."—P. M. Dysart.

Should we offer courses in mechanics, applied electricity, alternating currents, or advanced physics? If so what should be their character?

Another problem for the high-school teacher is presented by the decrease in the number of students electing high-school physics (see the ten-year summaries made by the United States Bureau of Education). Is this largely a question of the teacher and the preparation of the teacher? College departments of physics are in the largest degree concerned with the preparation of high-school teachers of physics. It is true that these prospective teachers are also exposed to courses in education in order to meet the requirements for teachers' certificates. Just how many of these theories in education will apply to classroom and laboratory instruction in physics is a question of some interest.

To summarize briefly an article by Professor E. C. Moore in the *School Review*, we need:

A realization by the teacher of the use of method—of the adaptation of the subject matter to the immature mind in the development of that mind; a realization of how much of the practical can be useful in bringing about the above; more preparation to teach each lesson; more talking on the part of the pupil; more study of the question and its relation to the class work and end desired; more study of the demonstration; hard work on the part of the pupil; more definite work, more of the coöperative spirit; the idea that each thing has its use if we may only see it; less soldiering; the attitude that there is more to learn; the belief that everything is in the nature of a problem; a realization that the teacher is a helper rather than a taskmaster.

How is the high-school teacher of physics to exemplify all this?

In connection with the high-school teacher's preparation for the teaching of physics, allow me to suggest also these needs:

1. A study of the teaching of physics to students of engineering, such as your committee under that title is now making. A syllabus, similar to the mathematical syllabus, will be a help, not as a master, but as a guide.

2. A published collection of lecture-table demonstration experiments. These should be simple, and preferably giving

alternative methods to allow for differences in apparatus. Such a test should be very clear as to the technical difficulties in the setting up and adjustment of apparatus to produce satisfactory results. Some indication of difficulties likely to be found in such adjustment, and the direction of attention to the physical principles involved would be a boon to the younger teacher in this subject.

3. A published collection of applications of physical principles found in other sciences and in elementary engineering theory and practice, to serve as a source of material for class demonstration, or for further study on the part of the class or of the teacher.

4. A published collection of questions for use in physics classes which would bring out practical applications or which could only be answered by thought processes functioning in terms of knowledge of physical principles. These should be such questions as were collected from schools throughout the country in a study made by Professor Edward L. Thorndike some years ago, and of the type suggested by him in an article in *School Science and Mathematics.*

5. A published collection of suggestions as to the requirements of the various branches of engineering work and the preliminary training which would seem to lead to success in each of these.

The problem of vocational guidance deserves careful consideration by this Society. To place before the high-school boy. through his teacher or vocational counsellor, trustworthy information regarding the requirements of engineering work would do much to set the parents and the boy himself right as to his future career. There is at present a woful ignorance on the part of those who are trying to "advise" boys along these lines.

"Engineering Addresses" by Waddell and Harrington is very useful along this line, and should have a wider circulation and distribution among high schools.

6. Some detailed study by the colleges on the work done by students coming from technical high schools, or from prepara-

tory schools in general when physics is offered for entrance. The product of the high-school physics course goes out into the business world or goes on to college; in either case it is usually lost to the high-school teacher forever. Even if a former pupil does return on a visit during the next year or two, at vacation time, he is not ready to summarize the deficiencies of his earlier training, and his later work is only known by the A to C or other letters of the alphabet expressing a first semester estimate of his "readers."

The committee offers the following questions for your consideration. Later certain of these may be laid before you with the request for written answers:

1. (*a*) Is elementary (high-school) physics required for entrance to your engineering courses? (*b*) If it is not required, is any distinction made in college work between those offering and those not offering high-school physics?

2. Do you admit on examination only or by credentials from approved schools?

3. Have you any figures (*a*) as to number entering from public high schools as compared with those from private or endowed preparatory schools? (*b*) From technical high schools as compared with academic or classical high schools?

4. Have you any figures as to the relative standing in physics of your entering students based upon the character of these preparatory schools (private or endowed school, technical high, or academic high)?

5. What courses in physics do you require of your engineering students?

6. What elective courses in physics are offered to engineering students?

7. Are any of these recommended strongly?

8. What provision is made for advising students as to these elective courses, or upon any questions of selection for future work?

9. Does the work given to the individual student depend at all upon that offered by him in preparation?

10. What is the aim of each of the courses you offer?

11. Can you suggest any means of closer coöperation between your physics department and those preparing your entering students?

12. Please indicate what, in your opinion, should be the distinction between high-school and college (engineering) physics as to method of presentation, extent of subject matter, laboratory work, etc.? What should be the dividing line to prevent unnecessary duplication and overlapping?

13. (*a*) What, in your judgment, should be the training of a high-school teacher of physics? (*b*) Of a college teacher of physics?

14. What part should a study of method of presentation of the subject take in this preparation?

15. In what way can the best results be obtained from (*a*) the recitation, (*b*) the lecture, (*c*) the demonstration, (*d*) the laboratory?

16. What, in your opinion, would best aid the high-school teacher in keeping up with the progress of the subject?

A valuable aid to the committee would be a continued study by a research student qualified for the work, along the lines suggested by Mr. George R. Twiss, high-school visitor of Ohio, to whom we are indebted for this part of the report. Mr. Twiss writes:

"It seems to me your best plan to get at the high-school and college physics situation would be to send out to the heads of the departments of physics in the engineering and other colleges a brief questionnaire asking a few direct and pointed questions such as can be answered by a few words each, specifically, leaving spaces for the answers, and asking for such further comments as they wish to make, to be placed on the back of the sheet. The following may suggest what I mean:

Are the majority of the high-school graduates coming to you deficient in:

(*a*) Knowledge of facts? Yes. No.
(*b*) Knowledge of meanings (definitions)?
(*c*) Knowledge of physical laws and principles?
(*d*) Knowledge of general concept and theories?

(*e*) Ability to raise and define problems?

(*f*) Ability to select and test hypotheses?

(*g*) Ability in manipulating apparatus?

(*h*) Ability to draw valid conclusions?

(*i*) Powers of observation?

(*j*) Habits of neatness, system and order in the laboratory and in the making of notes? Ability to use good English, spoken and written?

(*k*) Willingness to stick to tasks until done?

(*l*) Interest in the subject?

(*m*) Appreciation of its practical value?

(*n*) Ability to interpret phenomena and experimental data?

(*o*) Ability to use and apply elementary mathematics?

(*p*) Ability to draw and to read drawings?

Do you think that the causes of such deficiencies as exist lie more in the high-school students' training than in their lack of native ability?

Do the high-school teachers whom you know possess:

(*a*) Adequate knowledge of the subject matter?

(*b*) Sufficient command of teaching methods?

(*c*) The scientific spirit and attitude of mind?

(*d*) A sufficiently broad knowledge of related subjects?

(*e*) A sufficiently wide acquaintance with the application of physics?

Do the current high-school texts contain too much subject matter?

Is the amount of laboratory work generally attempted too great or too small in proportion to the amount of classroom work?

To what extent are you familiar at first-hand with the work done in high schools in physics?

What specific abilities are most needed by students in order to do successfully the work required of them in the physics *courses* in your institution?

What changes or improvements are needed in the teaching of *physics* in high schools? How may these changes best be brought about? What, if anything, is done in your institution toward preparing prospective high-school teachers of science?

A similar questionnaire should be sent to high-school teachers suggestive of their needs and their side of the question.

The only valid plan would be to make a comparison of high-school and college standings like that made by Professor Dearborn at Wisconsin (two bulletins, high-school and college standings issued by the Committee on Entrance Requirements, University of Wisconsin) for a large number of schools and analyze them with reference to different schools and different plans of teaching.

It would take several years to make such a study in a way that would really reveal anything. At least twenty different schools and colleges would have to be taken and the study covered through three or four years. It might then be shown how the pupils from each school do in all colleges and how the pupils from all schools do in each college. If notable differences were shown, then the particular schools could be investigated and perhaps the causes of success or lack of success could be learned. It could be done only by an organized campaign of coöperation. If all colleges and all high schools kept their grades as they are kept at the University of Missouri, it would be easy. If you send out your college questionnaire first, the results from it may suggest what to ask the high-school teachers. I think improvement, if it comes, must come through the use of the scientific or problem method in the teaching of science; through a broader experimental attitude toward *teaching problems,* and through a broader training of science teachers themselves. I believe that the college teachers lack and need this more than the secondary teachers even, because they *train* the secondary teachers. The high-school teachers tend to too narrow specialization. This may do for those in the technical high schools possibly, but not for those in the academic high schools."

So, if something can be done to collect and study the facts as to the students turned out from the high school and entering the engineering college, and to help the high-school teacher in growth and service, we may then be ready to publish a report correlating the work of high school and engineering college.

We must all instill in our students proper ideals of work, the power to do, and an appreciation of their place and obligations in service. Much of the technical and industrial side of their training must come in the experience gained after leaving school, whether it be of elementary, secondary or college grade.

Students, in some way, should come to realize that school offers them something worth while, and that hard work and continued work will be necessary for even average returns. It is only, then, by thoughtful coöperation between pupil and teacher and between all grades of educational institutions, that the best results may be obtained in preparation, whatever may be the goal.

Respectfully submitted,
H. T. Clifton,
L. F. Rondinella,
C. M. Wirick,
H. E. Webb, *Chairman.*

PROGRESS REPORT OF THE COMMITTEE ON STATISTICS.

The committee has succeeded this year in reducing the number of questionnaires sent out by individual interests. The offices of presidents, deans and registrars have in many cases been overtaxed by answering questions, some of them essentially the same but from independent sources. It is therefore urged of each member of this Society that the committee be informed of the nature of questionnaires before they are sent out, in order to avoid duplication. The Bureau of Education has consented to coöperate with the committee in obtaining statistics of attendance and in other ways aiding in the work.

The consideration of the members of the Society is directed to the subject submitted to the committee at the Princeton meeting. On June 24, 1914, the council took the following action: "That the Committee on Statistics be instructed to gather comparative statistics of scholarship in the engineering schools, of students entering respectively from (*a*) the Latin and English high schools and their equivalents and (*b*) the manual training, technical, and vocational high schools of the large cities, and report at the next convention."

The committee cannot make a final report in the matter of comparative statistics on the subject submitted to them. There are difficulties which can not be readily overcome in obtaining the particular data which would make a comparison worthy of serious consideration. The following is the most satisfactory information received up to the present time.

FROM THE REGISTRAR OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

"I have examined the records of all the students who were at the Institute in June, 1914, and have separated them into various groups. One of these groups was made up of students who came to the Institute from public technical schools and another group was made up of students who came to us from public non-technical schools. It is a fact that the standing of students who came to us from technical schools is less through the four years than the standing of the students who came to us from the non-technical schools. It is also true that the standing of these two groups varied in the same way in their first year when the effect of their preparation was felt probably more in their institute work than in any succeeding year. I have written an article based on this research which is being published in the January number of the *Technology Review.*

"I sent a memorandum in regard to this investigation to President Lowell of Harvard who answered my note by saying that the investigation confirmed his belief that the more general a student's preparation for college or professional school work, the better such a student will do in his college or professional school work."

FROM THE REGISTRAR OF THE UNIVERSITY OF ILLINOIS.

Comparative statistics of scholarship in the freshman year in the College of Engineering of the University of Illinois, 1913–14, of students admitted in September, 1913, from (*a*) manual training and technical high schools, (*b*) other high schools and academies, in the state of Illinois accrediting to the University of Illinois.

1. *General Averages.*

(*a*) Arithmetical average of average grades of 32 students from manual training and technical high schools	80
(*b*) Arithmetical average of average grades of 184 students from other high schools and academies	82

2. *Distribution of Averages.*

(*a*) Students from Technical and Manual Training High Schools.	(*b*) Students from other high schools and academies.

		Per Cent.
95–100	0	0.0
90– 94	3	9.5
85– 89	12	37.5
80– 84	4	12.4
75– 79	5	15.6
70– 74	6	18.8
65– 69	1	3.1
60– 64	0	0.0
Below 60	1	3.1
Total	32	100.0

		Per Cent.
95–100	1	0.5
90– 94	28	15.3
85– 89	53	29.0
80– 84	46	25.0
75– 79	34	18.4
70– 74	14	7.6
65– 69	4	2.2
60– 64	3	1.5
Below 60	1	0.5
Total	184	100.0

If it is desired that this subject be continued, the committee would be aided by an expression of opinion on the following: (1) Should a comparison be made only on arithmetical averages? (2) Should the comparative grades be based on the first year of college, on the first two years, or on all four years? (3) Should the student's high school record be taken into consideration?

The committee has formed its own opinion on the above points. The difficulty lies in obtaining sufficiently accurate data on which to base a safe general conclusion.

F. A. Barnes,
F. A. Fish,
J. D. Phillips,
H. H. Stoek,
A. J. Wood,
Chairman.

Discussion.

Professor H. S. Jacoby: May I inquire whether the committee received any statistics on this subject regarding the relative number of men who received marks below seventy—that is, including conditions, failures, etc., and which have some bearing on the question of mortality brought up yesterday by Dr. Mann.

Professor F. A. Fish: We secured no data on that subject.

PRELIMINARY REPORT OF THE COMMITTEE ON THE STANDARDIZATION OF TECHNICAL NOMENCLATURE.

The appointment of a committee on the standardization of technical nomenclature resulted from a protest on the part of a manufacturer against some of the technical terms in common use. This protest was written by Mr. D. M. Wright, and was published in the June, 1913, issue of the BULLETIN of the Society for the Promotion of Engineering Education. The following paragraphs, quoted from Mr. Wright's paper, show some of the results of our present inaccurate nomenclature and some of the advantages that would result from the use of clearer and more accurate terms.

"About two years ago, at the first hearing before the Senate Finance Committee in Washington of the so-called machine-tool builders in protest to the reduction then contemplated in protective tariff on their product, it was demonstrated that there was only a very vague idea of what a so-called machine tool consists. This confusion of understanding was further apparent from the fact that, while the manufacturers in a general way maintained that their product was a class of machines for working metal, it was impossible to define the line between their machines and others called metal-working machines, which were by some strange freak protected by a higher duty, although employing under similar conditions the same class of workmen. It can readily be seen that this confusion makes it possible to juggle names in the custom house, so that when it is convenient, any kind of machine for working metal can, by insistence, be classed either as a metal-working machine or a machine tool. Abundant proof is not lacking that this has been done to an extent that has amounted to a loss representing a comfortable fortune to the government each year and a direct advantage to foreign shippers. This has meant another large loss to American machine manufacturers. Many other illustrations might be given of the direct financial injury which results from the use of crude nomenclature, not only in mechanical engineering but in every art and industry.

"When a whole division of such an important profession as mechanical engineering cannot clearly describe its product, is it not time that something should be done? What difficulty is there in the way? Simply precedent springing from an acknowledged ignorant source.

"An effort has already been made to refine mechanical nomenclature, with such good results that a description of what has been done may promote interest in other departments of the language, and if finally a concerted effort were made to promote the use of preferred nomenclature in all the professions, this would certainly lead to the publication of text-books and a dictionary of preferred English nomenclature. Such concerted action would be of tremendous benefit not only as a refining agent, but also as a means of promoting a clearer understanding and a more accurate translation of the language, for one of the most important results of improvement in our nomenclature would be the commercial advantage of eliminating possible misunderstanding of terms in translation as well as in the custom house, in the courts, among students of the professions and among the general public."

The standardization of technical nomenclature is an enormous task and will require continuous work on the part of a number of committees. Some of the national engineering societies have for years been engaged in work of a similar nature, though their efforts have not been coördinated. Several of the national engineering societies have done very little in standardizing technical terms and have now no committees at work. There seems to be a peculiar fitness in the appointment of a committee from this Society for the purpose. Many of its members write text-books that become standards and thus give authority to technical terms as used by them. The members of this Society, then, are clearly the ones who should discuss and criticize new technical terms and proposed changes in technical terms now in common use. The busy writer will usually be glad of a list of terms that has run the gauntlet of criticism by this Society. A second reason for having the work done by a committee of this Society lies in the fact that our membership is made up of prominent engineers from all of the divisions of engineering. It should not, therefore, be difficult to secure criticisms and suggestions from the national societies of the several divisions of engineering through the influence of men in our own membership who are also prominent in the other national societies, nor should it be difficult to gain final acceptance of the lists of technical terms that may be published by this Society from time to time. In other words, this Society seems to be in a peculiarly advantageous position to act as a clearing house for technical terms.''

In order to make use of the work that had already been done by other societies in the preparation of approved lists of technical terms, letters were addressed to many of the American societies of engineering and to a number of foreign societies. A hearty spirit of coöperation has been shown. Such lists as were obtained have been incorporated in the list of terms given later in this report. A number of the societies are working upon lists that have not yet been completed.

To give some idea of the confusion that exists regarding spelling, hyphenating and abbreviations, the following quotations are taken from letters written by three different printers who do work for one of the most prominent American publishers of engineering books.

''In the matter of compounding, we avoid a multiplicity of hyphens—when they are not inserted by the author—as we find that in technical work especially there are so many words related to each other which many authors compound, that the hyphen occurs nearly as frequently as spaces. We use them where we consider the absence of the hyphen would cloud the sense, or give another meaning to the sentence.

''If the suggestion is of any use, though not at all in accord with our practice, we should advise the committee to note the compounding in the recently published edition of the Standard Dictionary."

"We have yours of the 25th inst. regarding a letter—on the question of standardizing styles of spelling and hyphenating of technical books.

"Our plan heretofore has been to follow Webster's Dictionary in the matter of hyphenating, spelling, etc., excepting when authors have insisted on their own style.

"We find on talking with our composition department that there are nearly as many styles as there are authors, and we would welcome any work which was accepted as a standard for the making of scientific books."

"We have your letter of June 25 in reference to spelling and hyphenating of words found in your series of books.

"We have laid this matter before our readers and they report that in the main spelling and hyphenation in this office is in accordance with Worcester. When Worcester is unsatisfactory, we use the Standard Dictionary. Unfortunately we cannot always adhere to either of these two books by reason of the authors insisting upon having their own method of spelling and hyphenating."

The list of terms given on the following pages was obtained from various sources, all of which are indicated. It is intended to show the spelling and hyphenating of certain terms and their abbreviations as suggested by various societies and individuals. In some instances terms are suggested to displace other terms that are in common use. The definitions of terms have not been given, since these will be generally known, and the original sources can be easily consulted when the definitions are desired. Most of the terms have been taken from lists that were prepared by men who are presumably experts in their fields. The list is offered for criticism by members of the Society, and additions to it of words that are written in two or more ways, or that are abbreviated in two or more ways, are solicited. No pretence is made to completeness in this list. While it is the largest and most varied list of the kind with which the committee is familiar, there are lists under preparation by certain societies that will form valuable contributions to this list. It is not desirable that such a list should be large. The criticisms and suggestions that are received will be considered by the committee before recommending approval by the Society of any list of terms. It is to be distinctly understood that the committee does not recommend a list at this time, but merely presents the list given in the following pages as a compilation of the work that has been done by other societies and individuals.

It has been suggested to the committee by a number of engineers and teachers, that a uniform list of symbols be prepared by the committee for torque, bending moment, unit stress, temperature, entropy and various other conceptions, and that these be urged as standards for the United States. Such standards seem eminently desirable. Your committee is not sure that such matters come within its jurisdiction. The matter of uniform symbols seems important enough to warrant the appointment of a separate committee to consider it. Instructions regarding the matter of standard symbols will be appreciated by your committee.

Term.	Abbreviation or Remark.	Reference.
air-tight mechanism		7
air compressor		4
adjustable-speed motors		9
alloy steel		1
alternating current	spell out, or a-c when used as compound adjective	8
alternating current		9
ammeter		9
amperes	spell out	3
amperes	spell out	8
asphaltic contents		10
back-gear handle		2
bevel gear		4
blister bar		1
blue print		4
boiler horse power	boiler h.p.	3
boiler horse power	boiler h.p.	8

Term.	Abbreviation or Remark.	Reference.
boiler room		4
boring machine	not boring mill	6
brake horse power	b.h.p.	3
brake horse power	b.h.p.	8
British thermal unit	B.t.u.	3
British thermal unit	B.t.u.	8
Brown and Sharpe gauge	B. & S. gauge	3
candle power	c.p.	8
candle-power	c-p.	3
carbon steel		1
carriage		2
carriage-way		10
cast steel		4
cast iron		1
cast iron		4
cement bar		1
centigrade	cent.	3
centigrade	cent.	8
centimetres	cm.	3
centimeters	cm.	8
change-gear box		2
circular mils	cir. mils	8
circular mils	cir. mils.	3
clay-working machinery		6
clutch-coupling		7
clutch pulley		7
coal tar		10
coke oven tar		10
compound gears		2
compound-rest top-slide		2
cone		2
cone gear		2
connecting rod		4
constant-current machines		9
constant-speed direct-current motors		9
constant-potential transformers		9
constant-speed motors		9
continuous current		9
converted bar		1
counter-clockwise convention		9
counter electromotive force	counter e.m.f.	8
cotton-working machinery		6
crank pin		4

Term.	Abbreviation or Remark.	Reference.
crank shaft		4
cubic	cu.	8
cubic	cu.	3
cut-off		4
cut-off		7
diameter	spell out	8
dieing machine	not power press	6
direct-connected engine		7
direct current	spell out, or d-c when used as compound adjective	8
direct current		9
direct-current compensator or balancer		9
direct-current generator		9
double-shear steel		1
drafting room		4
drilling machine	not drill or drill press	6
drop-press		4
electric horse power	e.h.p.	8
electric horse power	e.h.p.	3
electromotive force	e.m.f.	8
electromotive force	e.m.f.	3
engine room		4
equivalent sine wave		9
eye-bar		4
face gear		2
faceplate		2
Fahrenheit	fahr.	3
Fahrenheit	fahr.	8
feed gear		2
feed-gear segment		2
feed-rod gear		2
ferro alloys		1
feet	ft.	3
feet	ft.	8
figure	Fig.	3
fire tube		4
first-class		7
flywheel		7
follower guide		2
follow rest		2
foot-pounds	ft-lb.	8
foot-pounds per ton	ft-lb. per ton	3
footway		10
gallons	gal.	3

Term.	Abbreviation or Remark.	Reference.
gallons	gal.	8
gas-house coal tar		10
gas engine		4
gas producer		4
gas regulator		4
gas turbine		4
gear guards		2
grains	gr.	3
grains	gr.	8
gramme-calories	g-cal.	3
gram-calories	g-cal.	8
grammes	g.	3
grams	g.	8
gray cast iron		1
grinding machine	not grinder	6
hammer-head		4
headstock		2
high-duty		4
high-pressure		4
high-pressure cylinder	spell out	8
high pressure cylinder	spell out	3
high-priced		4
high-speed		4
horse power		5
horse-power hours		5
hot water heating system		4
hot-well		4
hours	hr.	8
inches	in.	8
inches	in.	3
index plate		2
indicated horse power	i.h.p.	8
indicated horse power	i.h.p.	3
induction generator		9
induction motor		9
ingot iron		1
ingot steel		1
intermediate gear		2
intermediate-gear segment		2
intermediate-gear stud		2
iron castings		1
kilogramme-calories	kg-cal.	3
kilogramme-calories	kg-cal.	8

Term.	Abbreviation or Remark.	Reference.
kilogram	kg.	8
kilogrammes	kg.	3
kilogramme-metres	kg-m.	3
kilogram-meters	kg-m.	8
kilometers	km.	8
kilometres	km.	3
kilovolts	kv.	8
kilovolt-amperes	kv-a.	8
kilowatts	kw.	3
kilowatts	kw.	8
kilowatt-hours	kw-hr.	3
kilowatt-hour		7
kilowatt-hours	kw-hr.	8
lathe bed		2
latent heat		4
leadscrew gear		2
leather-working machinery		6
linear	lin.	3
line-drop voltmeter compensator		9
liquid asphalt	do not use	10
live-center		7
load factor		9
low-duty		4
lower feed-cone		2
low-pressure		4
low-priced		4
low-speed		4
machine shop		4
machine tool	see metal-working machines	4
magnetomotive force	m.m.f.	3
magnetomotive force	m.m.f.	8
make-ready		4
make-up		4
malleable cast iron		1
mean effective pressure	spell out	8
mean effective pressure	spell out	3
metal drilling tools	not drills	6
metal grinding tools		6
metal turning tools	not lathe tools	6
metal-working machines	not machine tools	6
meters	m.	8
metres	m.	3
meter-kilograms	m-kg.	8

Term.	Abbreviation or Remark.	Reference.
metre-kilogrammes	m-kg.	3
microfarad	spell out	8
miles	mi.	8
miles	spell out	3
miles per hour per second	miles per hr.	3
miles per hour per second	mi. per hr. per sec.	8
milligrams	mg.	8
milligrammes	mg.	3
millimeters	mm.	8
millimetres	mm.	3
milling machine	not miller	6
milling tool	not cutter	6
minutes	min.	3
minutes	min.	8
mixer metal		1
motor-generator		9
mottled cast iron		1
multiple-cylinder		4
multispeeed motors		9
non-inductive load and inductive load		9
ohms	spell out	8
oil-gas tar		10
open-hearth		4
oscillating current		9
passenger car		4
per	spell out	8
per	spell out	3
per cent	% or per cent	3
percentage	per cent (or % in tabular matter)	8
per cent drop		9
phase difference		9
pig iron		1
piston rod		4
plant factor		9
planing machine	not planer	6
planing tools	not planer tools	6
plated bar		1
pounds	lb.	8
pounds	lb.	3
power-factor	spell out	8
power factor		9
power plant		4
pressure-temperature relation		7

Term.	Abbreviation or Remark.	Reference.
printing press		4
railroad car		4
revolutions per minute	rev. per min. (or r.p.m. in tabular matter)	8
revolutions per minute	rev. per min.	5
road-bed		10
road-metal		10
roadway		10
rod mill		4
rolling mill		4
sawing machine	not saw	6
second	sec.	3
seconds	sec.	8
second-class		7
semi steel		1
shaping machine	not shaper	6
shaping tools	not shaper tools	6
shear steel		1
shearing machine	not power shear	6
short-circuit stresses		9
shut-down		7
silk-working machinery		6
sine wave		9
slotting machine	not slotter	6
specific heat		4
spindle feed gears		2
single-hearth		4
single-phase		9
single-shear steel		1
spindle thrust-bearing		2
spur gear		4
square	sq.	8
square	sq.	3
square-root-of-mean-square	effective, or r.m.s.	8
stay bolt		4
steam heating or heat		4
steam piping or pipe		4
step bearing		4
steam boiler		4
steam jacket		4
steam power plant		4
steam turbine		4
stone-working machinery		6
street car		4

Term.	Abbreviation or Remark.	Reference.
street railway		4
stud gear		2
tailstock base		2
tailstock body		2
take-up		7
three-phase		9
thrust-bearing check nuts		2
ton-mile	spell out	8
tons	spell out	8
tons	spell out	3
tool block		2
toolpost		2
triple-expansion		4
tumbler-gear latch		2
tumbler-gear segment		2
turning machine	not lathe	6
unipolar machines		9
United States gallon	U. S. gal.	3
upper feed-cone		2
valve gear		4
varying-speed motors		9
volt-amperes	spell out	8
volt-ampere or apparent power		9
voltmeter		9
volts	spell out	3
volts	spell out	8
water-gas tar		10
water meter		4
water power		4
water tube		4
water works		4
watt-hours	watt-hr.	3
watt-hours	watt-hr.	8
watt-hour meter		9
wattmeter		9
watts	spell out	3
watts	spell out	8
watts per candle power	watts per c.p.	8
watts per candle-power	watts per c-p.	3
wave-form or wave shape		9
white cast iron		1
wood block pavement		10
wood-working machines	not machine tools	6

Term.	Abbreviation or Remark.	Reference.
wool-working machinery		6
worm gear		4
wrought iron		4
wrought iron		1
yards	yd.	8
yards	yd.	3
yield point		4
Miscellaneous Forms.		
3 in. by 6 in.		7
14 inches		3
3 in. long		7
3-in. valve		7
one twenty-fifth		7
three-sixteenths		7
three hundred twenty-two		7
twelve-inch main		7

1. From the report of committee 24, on uniform nomenclature of iron and steel, International Association of Testing Materials, Eighth Congress, New York, 1913. (Not accepted.)
2. Preferred names for lathe parts as determined by a ballot of builders of lathes. See *American Machinist*, April 24, 1913.
3. From the report of a committee to co-operate in standardizing abbreviations, symbols, punctuation, etc., in technical papers. *Proceedings of the American Society of Civil Engineers*, April, 1904 (Volume XXX, No. 4), pp. 174–177.
4. Taken from an old style sheet of the American Society of Mechanical Engineers.
5. From C. B. Going, editor, *The Engineering Magazine*.
6. Suggested by Mr. D. M. Wright.
7. From a list prepared by W. P. Cutter, librarian of the Engineering Societies, 29 W. 39th Street, New York.
8. A. I. E. E. standard abbreviations and notation, edition of February, 1913.
9. From Standardization Rules of the American Institute of Electrical Engineers. Edition of December 1, 1914.
10. Suggested by Mr. W. W. Crosby.

The foregoing is submitted to the society as a report of progress of the Committee on the Standardization of Technical Nomenclature for the year 1914–15.

John T. Faig,
Chairman.

DISCUSSION.

Professor G. B. McNair: In using a number of texts for non-electrical students. one fact has been rather noticeable throughout; and that is. that the writers of books particularly for non-electrical classes apparently make a point of using terms and letters not in accord with terms and letters used by writers of books intended for electrical students. If any book is examined with a view to its use for non-electrical classes. it is found that the author uses different letters throughout certain quantities. different from those he uses in books intended strictly for electrical students. It seems to me that is unnecessary. There is no particular call for each writer to adopt a different system of lettering from the one which is usually accepted. It seems that is certainly a bit of standardization which would not call for any changes.

Professor M. P. Cleghorn: I have been wondering if any attempt has been made by the committee or any other body to standardize the symbols used in engineering texts. In mechanics. for instance. Professor Church uses certain symbols for certain things. and several other authors of note use altogether different symbols for the same things. It is rather confusing. to say the least, not only to the instructor but to the student who studies the text and references. It seems to me there is a rich field here for standardization. and if it has not already been done. I would suggest that the committee take this up at an early date.

Professor W. S. Franklin: The American Institute of Electrical Engineers in conjunction with the British Institution of Electrical Engineers, long ago adopted terms and symbols which electrical engineers never depart from; and the rest of you might as well recognize and accept what has been done in their field with civil engineers in this matter because they did not take it up long ago. Electrical engineering men will not listen now to them. I. for my part. intend to stick to the recommendations of the American Institute of Electrical Engineers. as adopted internationally a number of years ago;

and I think every electrical engineer and nearly every physicist feels as I do. I think most decidedly we ought to give great weight to the recommendations of the American Institute in adopting standard symbols.

Professor C. M. Wirick: I am one of the few men who studied Esperanto. I have a list of international symbols published in Esperanto and translated into English, not only for the electrical branches, but for the international symbols in physics as well. I was rather surprised to learn that men use symbols to suit themselves, and let the other fellows understand them if they can. This was done years ago, and I supposed, of course, things had gone far enough to effect a change.

Discussion on Report of Institutional Delegates.*

Dean P. F. Walker: I would like to say just one word and that is, that we hope to extend the work and influence of the Society through the institutional membership as far as it is possible. I think I can safely speak for the committee by asking any of you who may come from institutions which are not institutional members, when you go back to your schools, to take the matter up with the heads of your institutions, and do whatever you can to bring about an interest in the Society.

Principal A. L. Williston: May I make one very simple suggestion? It seems to me that the possibilities for very important work by this committee of delegates are very great, but it also seems to me that a very large part of the usefulness of that work will be lost if a greater part of their deliberations and discussions are not in open meetings of the entire Society. My suggestion to the chairman of the committee and the Program Committee of next year is to try to arrange the program so as to have an entire session devoted to this which everybody may attend, because it seems that the questions which this committee is likely to take up will be the questions in which every member of this Society has the keenest interest, even if he is not an institutional delegate. I hope the work of the committee will develop in such a way and that the program will be so arranged that everybody may have a part in it.

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* This report is a duplicate of a report presented by Dean P. F. Walker to the Institutional Delegates on Thursday and is found on page 27.

Director J. E. Hayford: I want to agree very heartily with what Professor Williston has just said. It seems to me that the one danger in having this new wheel within a wheel is that we will have a breaking-up of the general meetings. Therefore, I would like to add my voice to his in urging that the meetings and discussions of the institutional delegates be at the general meetings.

Discussion of the Report of Committee on Committees.*

Professor W. S. Franklin: I would like to ask if it would not be possible to have the reports of the committees next year printed and circulated before the meeting, so that they could be read by the members and then make it possible to devote the larger part of the meetings to discussion of the reports?

Principal A. L. Williston: May I speak once more from my experience as secretary and in helping to plan programs? I have found this: that there are certain kinds of reports and certain kinds of matters presented on the program that should be printed and circulated long in advance, and the discussion also prepared in advance. I think it is very desirable to use all the effort we can in supporting the Secretary in attaining that result. I think that, on the other hand, there are a great many papers presented before the Society which are largely spoiled by being printed in advance; and it is not only a waste of the Secretary's time, effort and energy, but to some extent a waste of the Society's money in having such papers printed in advance. The effort to get the things that are important printed and before the Society at an early date is largely interfered with by the effort to get everything printed in advance. I understand that during the past year, at least, the wish of the council as expressed literally was that everything, without discrimination, be printed in advance, if possible. That is manifestly impossible. That gave the excuse for everybody to slide out under.

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* This report is a duplicate of a report presented by Professor H. S. Jacoby to Council and transmitted by Council to the meeting of the Society. It is found on page 9.

I do not know whether to make this as a suggestion to the Program Committee or to the Council or not, but I certainly believe that efficiency would be promoted if the powers having these matters in control would concentrate on a very few things and say frankly regarding the other things, we will not make any efforts at all. I am sure that I am right in this because of my own efforts as secretary two or three years ago, and in conversation with the present secretary I feel confident that he feels the same as I do about it.

Professor C. M. Wirick: I presented the report of the Committee on Secondary Education, and the results of weeks of work was practically wasted. The few who remained to hear the paper had no copies of it, had had no time to look it over, and it seems to me that the work is lost. Some of you will look over the report, some of you will not. Topics which should have come up for warm discussion will be buried somewhere. It seems that departmental meetings might be arranged. There are only a few chemists in the Society, but there are more than one hundred in the physics group. It is a question whether the report gets looked at. It seems to me that we should have departmental work. That may not be possible, of course. I had, I think, about twenty minutes for my report on chemistry, and again there was no chance for discussion of the report. It does seem to me that if we could have sections in physics and mathematics, and other meetings for the engineers who have common topics, if we could have departmental meetings as they do in the American Chemical Society, the net result would be very much better than now.

Professor F. C. Caldwell: To a certain extent I agree with what Professor Wirick has said. There certainly ought to be at least one session when we could meet by sections.

It seems to me that all the ordinary papers are better printed in advance, so that those interested can read them over, and so that they can be presented in abstract at the meeting. If there is a date fixed, by which material must be in, it would be as easy for the officers to get the work done at that time as a month later. Why not definitely adopt some date as other societies have done, after which nothing may be accepted except by consent of some authorized body. The Society is big enough and important enough so that it can be rather stringent in ruling on this matter. If a committee did not get its report in on time, it simply would not be considered and we could give much needed time to discussion of other reports.

I would therefore move that no matter received after May 1 be considered for presentation at the next meeting of the Society, except by unanimous consent of the program committee.

Dean C. L. Cory: I beg to make the following suggestion. Is May 1 not really earlier than is necessary? Commencement at the University of California occurs near the middle of May, and naturally—as I have no doubt has been the experience of all of you—a large amount of work accumulates toward the end of the term which must be completed before Commencement. Personally, I beg leave to express the hope that our Secretary might be willing to state that a later date than May 1 would be satisfactory, from his experience in such matters.

Before taking my seat, I beg to state, about sectionalizing the meetings of the Society, I take it that this is a Society for the Promotion of Engineering Education, and is not a society for the promotion of any particular branch of engineering. If we are interested in anything in this society, we are interested in education.

Therefore, it seems to me that we should be as much concerned with the report of the Committee on Secondary Schools, or the committee of institutional delegates as we are concerned with the discussion of the education of any particular type of engineer.

At this meeting the great desirability—yes, even necessity—of coördination has been repeatedly urged. Possibly the best expression of the necessity of coördination was given us yesterday evening, at the annual dinner, in the president's address. It does not seem possible for us to properly coördinate our engineering courses unless we all are well informed regarding the problems of the secondary school as well as the proper entrance requirements to our technical university courses.

I think Principal Williston's suggestion is an excellent one. All special committee reports should be presented at a general meeting of the Society so that we may understand the problem of engineering education rather than limiting our interests to special features with which we may largely be individually interested.

Professor Wirick: It is well enough to talk about being interested in all of the work. I noticed a paper, which seemed to me good—one on thermodynamics. A whole lot of people were not interested in it. I think we should have departmental meetings and then have one general session each day for discussion of these results. I do not quite like the assertion that we are not interested in anything except our own branches.

Professor H. S. Jacoby: Some of these investigations by the committee might just as well be started early. That was the idea in creating the Committee on Committees. In some of these investigations it ought not to take a very long time to get the material together, and then this can be digested and put into final shape. It seems as if some of the reports, especially where a committee has more than one topic to discuss, might be sent to the office long before the required time.

so there would not be so many reports coming in at the last moment.

Principal Williston: It seems to me that we appoint committees for the purpose of exercising better judgment in matters in which they have an opportunity for more detailed experience than the members of the Society as a whole can have, and for that reason we have a definite rule in our constitution requiring all large matters to be decided upon by the Council, and making it unconstitutional for members at a meeting like this, where somebody makes a good suggestion which seems to appeal to those present, to pass on it at all. It seems to me that we select our committees with care, that the purpose of these committees is to exercise that judgment better than we, in open meeting, with little thought and opportunity for intimate knowledge of conditions, can do. I would like, as a substitute for the motion before us, and as an endorsement of the constitution of our committees, to refer this matter to the Program Committee for its good judgment without instruction from the Society. I offer that suggestion as a substitute.

Professor Caldwell: I would not be willing to accept the substitute. This is an important matter, one where the membership is considerably interested, and it would be well for the Program Committee to have the expression of the Society's wishes back of it.

Professor J. F. Merrill: Many of us do not know what is for the best interests of the Society. We certainly want to do that which will be for its best interests. If the Program Committee feel, because of their experience, that they want the material in no later than May 15, then we want it that way. If they feel, however, that there may be times when the copy could come in later, then that would do for us. Many of us do not know how to vote on this question.

Dean G. C. Anthony: It would seem to cover all contingencies, because the unanimous consent of the officers may change the date for any particular case. I should have been glad to have the backing of the Society as to the final date when I was president and should have welcomed such a motion. I do not know how the president-elect feels about it.

The substitute offered by Principal Williston was put to a vote and lost.

The original motion, to set the date for May 15 with authority given to the Program Committee to change the date by unanimous consent, was carried.

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N. C. State College

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